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Normative data for verbal fluency and naming tests in Spanish-speaking adults in the United States

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Abstract.
BACKGROUND: Linguistic deficits are common across neurological and neurodegenerative disorders. Currently there are limited neuropsychological norms available for Spanish-speaking adults residing in the U.S.
OBJECTIVE: To generate norms for two verbal fluency tests and the Boston Naming Test (BNT) in a Spanish-speaking population in the U.S., with adjustments for demographic and cultural variables.

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METHODS: The sample consisted of 245 adults from the U.S. Participants completed phonological and semantic verbal fluency tests and the BNT. A standardized four-step statistical procedure was used.
RESULTS: For the phoneme F, interactions between Spanish proficiency, age, and education arose. Better performance on phonemes A, S, and M was related to education. Spanish proficiency, acculturation, and time in the U.S. were associated with the phonemes S, A, P, M, and R. An age by education interaction was found for phonemes M and R. The FAS and PMR triads were related to age, sex, time in U.S., and Spanish proficiency. For the semantic verbal fluency tests, an interaction between education and Spanish proficiency arose. For the BNT, test scores were related to education, and significant interactions were also found based on education's interaction with Spanish proficiency and acculturation.
CONCLUSION: This study highlights the importance of accounting for sociodemographic and acculturative factors when developing normative data for verbal fluency tests and the BNT for dominant Spanish-speaking adults in the U.S. These sociodemographically-adjusted norms will help improve accuracy of diagnosis and interpretation of linguistic test performance in Spanish speakers living in the U.S.

Keywords: Verbal fluency, Boston Naming Test, Hispanic, Bayesian inference, normative data

1. Introduction

The United States is undergoing a rapid transformation in racial/ethnic diversity, with the Hispanic population emerging as the largest racial/ethnic minority group, comprising 63.7 million people (19.1% of the population; U.S. Census Bureau, 2023). Additionally, Spanish is the most prevalent non-English language spoken both at home and in the community, boasting approximately 41–42 million speakers. A large percentage of Hispanics are also bilingual in English and Spanish. According to the U.S. Census Bureau (2019; in Dietrich & Hernandez, 2022), 61.4% of Spanish speakers self-reported speaking English as "very well".

Hispanics exhibit increased susceptibility to numerous neurological disorders, including neurodegenerative conditions such as mild cognitive impairment and Alzheimer's disease (Vega et al., 2017; Alzheimer's Association, 2021), as well as acquired brain injuries such as stroke (Gardener et al., 2020). Contributing factors include a higher prevalence of diabetes, depression, low income, and low educational attainment (Vega et al., 2017; Alzheimer's Association, 2021), as well as disparities in healthcare access and utilization (Saadi et al., 2017).

Accurate and reliable neuropsychological assessments are crucial for the diagnosis of rehabilitation planning of individuals with neurological disorders. In large part, clinical neuropsychologists base their diagnoses on the interpretation of neuropsychological test results. Verbal fluency tests, being highly sensitive to brain damage and cognitive decline associated with aging or neurodegenerative diseases (Álvarez-Medina et al., 2023), they are commonly included in neuropsychological batteries due to their simplicity, brevity, and ease of administration. Among practitioners providing neuropsychological services in Spanish in the U.S., letter verbal fluency is the most frequently used language measure (24%; Gasquoine et al., 2021).

However, clinicians face significant challenges when interpreting the neuropsychological test results of their Hispanic patients, not only due to their diverse backgrounds (e.g., national origin, English proficiency, acculturation level, and socioeconomic status), but also because of the limited availability of normative data for this population. Gasquoine et al. (2021) discovered that practitioners in the U.S. often interpret Spanish language tests using norms generated in the continental U.S. However, the majority of these available norms were established before 2010 and focused on semantic verbal fluency (primarily the animal´s category) for middle-aged and older individuals (>40 years old) residing along the Mexico/U.S. border (California, New Mexico, and Texas; Ponton et al., 1996; Artiola I Fortuny, 1999; La Rue et al., 1999; González et al., 2005; Mack et al., 2005; O'Bryant et al., 2017; Hall et al., 2017), Florida (Acevedo et al., 2000; Roselli et al., 2009), and Northern Manhattan (Stricks et al., 1998). Existing norms also vary concerning Hispanic origin (some requiring inclusion criteria for people living in the U.S. having arrive from Spanish-speaking countries, while others accepted Hispanic ancestry as inclusion criteria) and language of administration (exclusively Spanish or both Spanish and English). Furthermore, Gasquoine et al. (2021) noted that U.S neuropsychologists also utilize norms from Latin American countries or Spain (e.g., Olabarrieta-Landa et al., 2015) for interpreting Spanish language tests (Casaletto et al., 2016;

delCacho-Tena et al., 2023). The risk of misdiagnosis is increased in all of these scenarios where the clinician is relegated to utilizing norms based on populations different from the patient being evaluated.

Given this neuropsychology landscape for Hispanic Americans, it has become evident that updated and more granular normative data for Spanish speakers in the U.S. are essential. Based on this need, Rivera Mindt et al. (2021) initiated. "The Neuropsychological Norms for the U.S.-Mexico Border Region in Spanish (NP-NUMBRS)" project, aiming to generate norms for various neuropsychological tests, including phonological and semantic verbal fluency tests (Marquine et al., 2021). Participants were administered the letters PMR and the animals category in Spanish. As with previous efforts, age and education were primary predictors in the models to generate norms, while sex did not emerge as a significant factor.

Despite significant progress in providing tools for clinicians offering services to Spanish speakers in the U.S., plenty remains to be covered. Rivera Mindt et al. (2021) outlined the limitations of the NP-NUMBRS project and proposed future directions for advancing the field. For instance, while the project generated norms for native Spanish speakers from the U.S. (California/Arizona)-Mexico border region aged 19 to 60, caution was advised when applying these norms to Spanish-speaking populations from other unexamined regions (e.g., Northern U.S.). Additionally, considering that reference values are most precise in the year of their creation (Mitrushina et al., 2005) and that the data for this project were collected in two cohorts (1998–2000 and 2006–2009) prior 2010, more recent norms are needed. Recognizing that sociocultural variables can impact cognitive performance, and that second and third generation Hispanics living in the U.S. may retain their Spanish language, identity, and other aspects of their culture and ancestry, future normative data for verbal fluency tests should also incorporate relevant variables associated with fluency performance in bilingual Hispanic samples, such as degree of bilingualism, acculturation, and age of language acquisition (Bennett & Verney, 2019).

Consequently, the objective of this study was to establish norms for phonological (/f/, /a/, /s/, /p/, /m/, and /r/ phonemes) and semantic (animals and fruits categories) verbal fluency tests in a sample of Spanish speakers residing in various regions in the U.S. We posit that clinical neuropsychologists would benefit from updated norms for these verbal fluency tests, allowing them to select the most suitable available norms that align with the sociocultural characteristics of their patients (Rivera Mindt et al., 2021).

2. Materials and methods

2.1. Participants

The initial sample consisted of 253 healthy individuals who were recruited from the U.S. (California, Connecticut, Florida, Indiana, New Jersey, Oregon, Virginia, and Wisconsin). To participate in the study, individuals met the following eligibility criteria: a) be between 18–80 years of age, b) have been living in the U.S. for at least 1 year (12 continuous months), c) self-identify Spanish as their "dominant language", d) have at least 1 year of formal education, e) be able to read and write in Spanish, f) obtain a score of ≥ 23 on the Mini-Mental State Examination (MMSE) (Folstein et al., 1975; Villaseñor-Cabrera et al., 2010), g) obtain a score of ≤ 10 on the Patient Health Questionnaire–9 (PHQ-9) (Kroenke et al., 2001), and h) obtain a score of ≤ 10 on the Generalized Anxiety Disorder-7 (GAD-7) (Spitzer et al., 2006).

Individuals were ineligible if any of the following exclusion criteria were present: a) history of a neurodevelopmental disorder, b) history of a learning disorder, c) past or present neurological condition, d) past or present chronic medical condition that might affect cognition (e.g., metabolic syndrome, chronic heart failure, sleep apnea, complications associated with SARS-CoV-2), e) past or present use of psychotropic medications that might affect cognition, f) past or present history of substance abuse or dependence, or g) past or present history of a psychiatric disorder.

Eight participants were excluded from data analysis due to incomplete sociodemographic information, resulting in a final sample of 245 participants. The majority of the sample was comprised of women (60.8%, $n = 149$), the mean age was 41.1 (SD = 14.9), and the mean years of school completed was 15.1 (SD = 4.2). Sociodemographic characteristics are reported by Rivera et al. (2024).

Each of the institutions obtained their own institutional review board protocol approval to cover the ethical conduct of the study at their own site. All participants signed an informed consent form and were offered $25 for their participation in the study.

2.2. Measures

For the present study, phonological and semantic verbal fluency tests were administered in Spanish. Participants were asked to provide as many words as possible within 60 seconds in each of the six phonemes (/f/, /a/, /s/, /p/, /m/, and /r/) and two categories (animals and fruits). Olabarrieta-Landa et al.'s (2017) administration and scoring guidelines were followed. For this study, the total score was used.

Participants also completed the standard (60-item) Spanish version of Boston Naming Test (BNT) that differs slightly from the original BNT (Kaplan et al., 1983). For example, item 14 is a carrot instead of a mushroom, item 19 is a muffin instead of a pretzel, item 28 is a crown instead of a wreath, item 40 is a pacifier instead of a knocker, item 48 is a needle instead of a noose, item 51 is a keyhole instead of a latch, and item 57 is a watering can instead of a trellis. The BNT total score is the sum of correct spontaneous answers plus correct answers followed by a semantic clue (Kaplan et al., 2005). The administration of the BNT was conservative, and thus synonyms were not considered correct responses.

It should be noted that although a large portion of the sample was bilingual, participants were required to provide responses only in their dominant language of Spanish. Therefore, credit was not given for any correct English responses.

2.3. Statistical analysis

The detailed statistical analyses used to generate the normative data for this test are described in Rivera et al. (2024). In summary, since the verbal fluency total score consisted of the number correct words produced in 60 seconds $[Y_i \ (i = 1, \ \ldots, \ n)]$, Poisson distribution was assumed $[Y_i \sim Po(\mu_i)]$. However, BNT total score was considered as 60 trials or attempts, where each trial can be classified as success or failure, assuming a binomial distribution $\left[Y_i \sim Bin\left(m_j, \ \pi_j\right)\right]$, where m is the total number of trials ($m = 60$) and π is the probability of success on each trial.

A Bayesian approach was adopted to determine which variables should be included as predictors, wherein the available prior information was combined with the information from the data. This combination is summarized in a posterior probability distribution for each unknown quantity in the model. In the variable selection procedure, the unknown quantity is the true model and, for each of the 2^p combinations, where p refers to the number of covariates, a candidate is obtained that may be potentially related to the output (Li & Clyde, 2018).

The full regression models included as predictors: age, age^2, education (log- transformed), sex, the Bidimensional Acculturation Scale for Hispanics (BAS; Marin & Gamba, 1996), the Bilingual Dominance Scale (BDS, Dunn & Fox, 2009), and all two-way interactions between these variables. Age was centered (age in years – $\bar{X}_{Age}$ in the sample) before computing quadratic age to avoid multicollinearity (Kutner et al., 2005). Once the variables were selected, the model estimations were obtained using Poisson and Binomial regression models, respectively. The models can be expressed as follows:

$$\mu_i = e^{\beta_0} \cdot e^{\beta_1 X_i^{(1)}} \cdot \ldots \cdot e^{\beta_p X_i^{(p)}},$$

to Poisson case, and

$$logit\left(\pi_j\right) = \log\left(\frac{\pi_j}{1 - \pi_j}\right),$$

to binomial case. This means that a change of one unit in any of the variables would suppose that the mean number of words is multiplied by e^{β_p}. Prior distributions for each of the unknown parameters $(\beta_0, \ \beta_1, \ \ldots \ \beta_p)$ followed a normal distribution centered at 0 and with large variance (i.e., $\sigma^2 = 1.0 \times 10^4$ and $\tau = 1.0 \times 10^{-3}$). This choice was made to reflect a non-informative or weakly informative prior. By centering the distribution at 0, we express the belief that, a priori, the parameters are equally likely to be positive or negative, without strong prior knowledge favoring any particular direction. The large variance ensures that the prior distribution is diffuse, allowing the data to play a dominant role in the posterior inference. This approach is particularly useful in scenarios where there is little prior information available or when we want to minimize the influence of the prior on the posterior results (see Bayarri et al., 2012; Garcia-Costa et al., 2022). The large variance indicates that we are open to a wide range of possible values for the parameters, reflecting our initial uncertainty.

The Bayesian inference procedure was performed using Markov Chain Monte Carlo methods through the software JAGS (Just Another Gibbs Sampler) and its R interface *rjags* (Plummer, 2022). For the convergence of three chains for each parameter, a burning period was used. A total of 3000 samples of each posterior distribution were left.

3. Results

3.1. Variable selection

Twenty-nine possible candidate covariates were examined. Table 1 shows the posterior inclusion probability (PIP) values of all covariates in each neuropsychological score. From the PIPs, an elbow plot (x-axis=each covariate, y-axis=PIP values) was made and the substantial change in PIPs was studied to select variables for the regression model for each neuropsychological score (Table 1).

3.2. Phonological verbal fluency

Table 2 presents the mean, median, mode, and credibility interval (95%) of the posterior distributions for the for the parameters in each model. The final model for /f/ showed that age by BDS interaction arose, such that people over 50 years old who had higher English competence generated more words than those with higher Spanish proficiency. However, people younger than 50 years old with higher Spanish proficiency produced more words than those with higher English competence (Fig. 1A). Also, an education by BDS interaction was found, such that after ten years of education, people with higher Spanish proficiency produced a greater number of words than those with higher English proficiency. However, people with fewer than ten years of education but higher English proficiency produced more words than those with higher Spanish proficiency (Fig. 1B).

Education was related to the /a/ phoneme, such that scores increased according to education's natural logarithmic transformation (Fig. 1C). Moreover, a sex by BDS interaction was found, such that women with higher Spanish competence produced a greater number of words whereas men did not (Fig. 1D). Finally, a sex by time in the U.S. interaction was found, such that women with a greater number of years living in the U.S. generated fewer words, whereas men generated a greater number (Fig. 1E).

The /s/ phoneme was also associated with education, such that scores increased according to education's natural logarithmic transformation. Furthermore, a BAS by time in the U.S. interaction was found, such that people who spent a greater number of months in the U.S. and had lower Hispanic acculturation performed better on this phoneme. However, people with fewer months living in the U.S. but higher Hispanic acculturation achieved higher scores (Fig. 1F). Moreover, a sex by BDS interaction was found, such that women with higher Spanish proficiency produced a greater number of words whereas men did not.

Regarding the /p/ phoneme, an age by education interaction was found, such that people with greater years of education and older age achieved higher scores compared to older people with fewer years of education (Fig. 1G). Furthermore, a sex by BDS interaction was found, such that women with higher Spanish proficiency produced a greater number of words, while men maintained their level of performance regardless of their Spanish or English proficiency. Finally, a BAS by time in the U.S. interaction was found, such that people with higher Hispanic acculturation performed better on this phoneme regardless of the time spent in the U.S. However, people with lower Hispanic acculturation perform worse if they had spent more time in the U.S.

For the /m/ phoneme, scores increased according to the natural logarithmic transformation of education. A sex by BDS interaction was found, such that men generated a greater number of words with higher English competence compared to women, but with higher Spanish competence, women produced a greater number of words (Fig. 1H). Finally, a BAS by time in the U.S. interaction was found, such that people with higher Spanish acculturation and more time living in the U.S. performed worse compared to those living in the U.S. for less time. However, when people had lower Hispanic acculturation, they performed equally well regardless of the time living in the U.S.

Finally, for the /r/ phoneme, an age by education interaction arose, such that people with greater years of education and older age performed much better than those with fewer years of education (Fig. 1I). Lastly, a sex by BDS interaction was found, such that women produced a greater number of words with greater Spanish proficiency, while men produced fewer words.

3.3. Summatory scores for FAS and PMR triads

Summatory score for FAS triad showed an education by BDS interaction, such that after 10 years of education, people with higher Spanish competence produced a greater number of words than those with higher English competence. However, people with fewer than 10 years of education but higher English competence produced a greater number of words than those with higher Spanish competence. Also, a sex by time in the U.S. interaction was found, such that

Table 1

Posterior inclusion probabilities (PIP) to variable selection by each test score

Covariable	Phoneme F	Phoneme A	Phoneme S	Phoneme M	Phoneme R	Animals	Fruits	BNT	FAS	PMR
Intercept	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Age	0.266	0.123	0.224	0.181	0.234	0.037	0.075	0.053	0.155	0.549
Age^2	0.061	0.052	0.064	0.089	0.088	0.022	0.029	0.030	0.213	0.226
log(education)	0.536	0.801	0.940	0.838	0.884	0.948	0.755	0.109	0.71	0.742
Sex (Woman)	0.101	0.112	0.053	0.131	0.069	0.040	0.191	0.102	0.419	0.076
Time in U.S.	0.255	0.219	0.263	0.199	0.234	0.321	0.126	0.044	0.227	0.204
BAS-Hispanic	0.100	0.086	0.099	0.235	0.201	0.066	0.040	0.056	0.336	0.436
BDS	0.487	0.064	0.064	0.229	0.058	0.274	0.395	0.174	0.291	0.074
Age*Age^2	0.076	0.055	0.059	0.052	0.091	0.023	0.032	0.042	0.133	0.299
Age**log*(education)	0.365	0.164	0.454	0.316	0.557	0.043	0.071	0.043	0.266	0.882
Age*Sex (Woman)	0.149	0.064	0.071	0.122	0.173	0.024	0.029	0.023	0.832	0.145
Age*Time in U.S.	0.075	0.114	0.127	0.125	0.154	0.050	0.073	0.029	0.109	0.137
Age*BAS-Hispanic	0.180	0.115	0.255	0.149	0.159	0.034	0.066	0.050	0.132	0.148
Age*BDS	0.456	0.085	0.051	0.062	0.072	0.025	0.043	0.102	0.156	0.078
Age^2**log*(education)	0.066	0.057	0.076	0.143	0.075	0.022	0.031	0.044	0.289	0.346
Age^2*Sex (Woman)	0.170	0.265	0.467	0.237	0.320	0.036	0.025	0.055	0.974	0.993
Age^2*Time in U.S.	0.086	0.125	0.069	0.099	0.061	0.022	0.028	0.022	0.244	0.272
Age^2*BAS-Hispanic	0.057	0.051	0.071	0.062	0.076	0.022	0.030	0.034	0.274	0.278
Age^2*BDS	0.046	0.048	0.060	0.054	0.072	0.023	0.098	0.035	0.108	0.207
log(education)*Sex (Woman)	0.088	0.121	0.051	0.163	0.067	0.046	0.271	0.113	0.202	0.074
log(education)*Time in U.S.	0.203	0.216	0.266	0.183	0.402	0.313	0.108	0.042	0.234	0.41
log(education)*BAS-Hispanic	0.161	0.081	0.100	0.220	0.188	0.070	0.052	0.595	0.336	0.396
log(education)*BDS	0.613	0.061	0.070	0.228	0.057	0.688	0.460	0.800	0.551	0.075
Sex (Woman)*Time in U.S.	0.268	0.884	0.045	0.232	0.124	0.077	0.063	0.381	0.983	0.104
Sex (Woman)*BAS-Hispanic	0.095	0.121	0.058	0.096	0.075	0.036	0.125	0.111	0.401	0.081
Sex (Woman)*BDS	0.062	0.947	0.738	0.458	0.976	0.022	0.039	0.037	0.294	0.999
Time in U.S.*BAS-Hispanic	0.316	0.061	0.524	0.507	0.397	0.235	0.137	0.074	0.207	0.516
Time in U.S.*BDS	0.110	0.051	0.048	0.075	0.099	0.036	0.052	0.085	0.117	0.098
BAS-Hispanic*BDS	0.130	0.079	0.068	0.241	0.076	0.078	0.182	0.086	0.181	0.073

*Note** BAS = Bidimensional Acculturation Scale for Hispanics; BDS = Bilingual Dominance Scale.

Table 2
Mean, median, mode, and credibility interval (95%) for the posterior distributions of the parameters in the phonologic verbal fluency models

Test score	Parameters	Mean	Median	Mode	HDI Low	HDI High
Phoneme F	Intercept	1.9896	1.9986	2.0079	1.5243	2.4650
	Age	0.0073	0.0074	0.0077	0.0032	0.0115
	log(education)	0.1104	0.1067	0.0951	–0.0552	0.2864
	BDS	–0.0389	–0.0392	–0.0381	–0.0659	–0.0072
	Age*BDS	–0.0004	–0.0004	–0.0004	–0.0007	–0.0002
	log(education)*BDS	0.0169	0.0169	0.0165	0.0060	0.0273
Phoneme A	Intercept	1.3913	1.3855	1.3563	1.0448	1.7677
	log(education)	0.3660	0.3679	0.3733	0.2270	0.4803
	Sex	0.1202	0.1197	0.1105	–0.0431	0.2795
	Time in U.S.	0.0002	0.0002	0.0002	–0.0002	0.0006
	BDS	–0.0003	–0.0004	–0.0008	–0.0055	0.0050
	Sex*Time in U.S.	–0.0008	–0.0008	–0.0008	–0.0013	–0.0003
	Sex*BDS	0.0105	0.0106	0.0110	0.0042	0.0172
Phoneme S	Intercept	1.5130	1.5149	1.5371	0.7843	2.1927
	log(education)	0.2645	0.2638	0.2604	0.1455	0.3880
	Sex (Woman)	–0.0304	–0.0291	–0.0247	–0.1481	0.0806
	Time in U.S.	0.0007	0.0007	0.0007	–0.0010	0.0025
	BAS-Hispanic	0.0726	0.0739	0.0816	–0.1049	0.2495
	BDS	0.0050	0.0050	0.0044	–0.0005	0.0112
	Time in U.S.* BAS-Hispanic	–0.0003	–0.0003	–0.0003	–0.0008	0.0002
	Sex*BDS	0.0060	0.0059	0.0057	–0.0006	0.0126
Phoneme P	Intercept	1.8927	1.9073	1.9708	1.2915	2.5336
	Age	–0.0120	–0.0120	–0.0119	–0.0312	0.0063
	log(education)	0.3010	0.3004	0.3072	0.1901	0.4222
	Sex	–0.0074	–0.0065	–0.0042	–0.1131	0.1022
	Time in U.S.	–0.0002	–0.0001	0.0000	–0.0017	0.0014
	BAS-Hispanic	–0.0010	–0.0017	–0.0047	–0.1626	0.1455
	BDS	–0.0004	–0.0005	–0.0013	–0.0065	0.0051
	Age* *log*(education)	0.0064	0.0064	0.0065	–0.0006	0.0135
	Sex*BDS	0.0071	0.0072	0.0073	0.0003	0.0134
	Time in U.S.* BAS-Hispanic	–0.0002	–0.0002	–0.0002	–0.0006	0.0003
Phoneme M	Intercept	1.5301	1.5614	1.5997	0.8639	2.0908
	log(education)	0.3677	0.3694	0.3791	0.2506	0.4803
	Sex	0.0231	0.0235	0.0278	–0.0977	0.1320
	Time in U.S.	0.0004	0.0004	0.0004	–0.0011	0.0021
	BAS-Hispanic	–0.0128	–0.0170	–0.0272	–0.1600	0.1553
	BDS	0.0072	0.0073	0.0075	0.0009	0.0127
	Time in U.S.* BAS-Hispanic	–0.0003	–0.0002	–0.0002	–0.0007	0.0002
	Sex*BDS	0.0047	0.0047	0.0049	–0.0019	0.0116
Phoneme R	Intercept	1.5296	1.5337	1.5674	1.1931	1.8878
	Age	–0.0173	–0.0169	–0.0137	–0.0378	0.0044
	log(education)	0.3358	0.3358	0.3325	0.2147	0.4664
	Sex	–0.0770	–0.0780	–0.0805	–0.1823	0.0289
	BDS	0.0008	0.0009	0.0008	–0.0047	0.0057
	Age**log*(education)	0.0073	0.0072	0.0072	–0.0004	0.0155
	Sex*BDS	0.0123	0.0122	0.0122	0.0057	0.0185

Note: *Interaction; BAS = Bidimensional Acculturation Scale for Hispanics; BDS = Bilingual Dominance Scale; HDI = Highest Density Intervals.

women with a greater number of years living in the U.S. generated fewer words, whereas men a greater number. Finally, an age by sex interaction arose, such that while men's performance maintained stable with increasing age, women's performance improved with increasing age until they reached age 65 after which a decline in performance was observed.

On the other hand, summatory score for PMR triad showed a sex by BDS interaction, such that men generated a greater number of words with higher English competence compared to women, but with higher Spanish competence, women produced a greater number of words. Moreover, an age by education interaction was found, such that people with greater years of education and older age achieved higher scores compared to older people with fewer years of education. Finally, as with FAS triad, an age by sex interaction arose, such that while men's performance

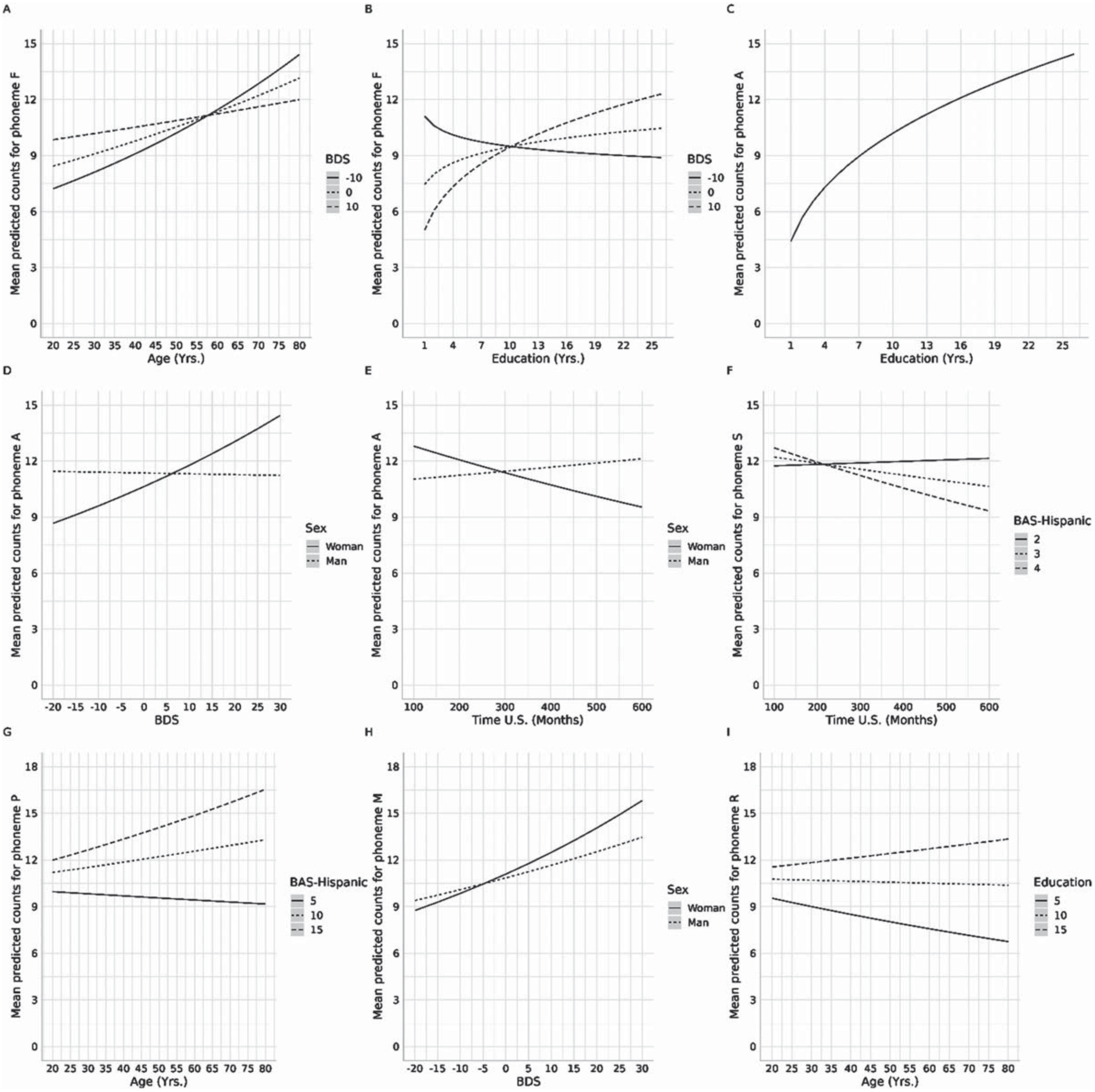

Fig. 1. Predicted mean count as a function of demographic variable included in the phonologic verbal fluency models. *Note:* BAS = Bidimensional Acculturation Scale for Hispanics; BDS = Bilingual Dominance Scale.

maintained stable with increasing age, women's performance improved with increasing age until they reached age 65 after which a decline in performance was observed (see Table 3).

3.4. Semantic verbal fluency

For Animal and Fruit categories, an education by BDS interaction was found, such that after 5 years of education, people with higher education and greater Spanish proficiency produced a greater number of animals than those with greater English proficiency. However, in fruits category, the differences between Spanish and English proficiency were maintained regardless of educational attainment, and people with greater Spanish proficiency always produced a greater number of fruits (Fig. 2A, B). See Table 4 for mean, median, mode, and credibility interval (95%) for the posterior distributions for the of the parameters for each model.

Table 3
Mean, median, mode, and credibility interval (95%) for the posterior distributions of the parameters in total sum of words for phonemes models

Test score	Parameters	Mean	Median	Mode	HDI Low	HDI High
Total sum of /f/a/s	Intercept	2.8676	2.8680	2.8538	2.5675	3.1510
	Age	0.0009	0.0009	0.0007	–0.0015	0.0038
	Age^2	0.0001	0.0001	0.0001	0.0000	0.0002
	log(education)	0.2153	0.2141	0.2137	0.1080	0.3242
	Sex (Woman)	0.2006	0.2002	0.1942	0.1175	0.2835
	Time in U.S.	-5.47×10^{-6}	-6.76×10^{-6}	-7.36×10^{-6}	–0.0002	0.0002
	BDS	–0.0148	–0.0149	–0.0168	–0.0318	0.0029
	Sex (Woman)*Time in U.S.	–0.0008	–0.0008	–0.0007	–0.0011	–0.0005
	Age*Sex (Woman)	0.0063	0.0063	0.0060	0.0028	0.0096
	Age^2*Sex (Woman)	–0.0003	–0.0003	–0.0004	–0.0005	–0.0002
	log(education)*BDS	0.0072	0.0072	0.0071	0.0004	0.0132
Total sum of /p/m/r	Intercept	2.6808	2.6823	2.6994	2.4784	2.8567
	Age	–0.0209	–0.0208	–0.0200	–0.0326	–0.0093
	Age^2	0.0002	0.0002	0.0002	0.0001	0.0003
	log(education)	0.3246	0.3243	0.3182	0.2577	0.3952
	Sex (Woman)	–0.0238	–0.0242	–0.0284	–0.0813	0.0412
	BDS	0.0026	0.0026	0.0025	–0.0002	0.0058
	Age*Sex (Woman)	0.0015	0.0016	0.0017	–0.0018	0.0047
	Age^2*Sex (Woman)	–0.0004	–0.0004	–0.0005	–0.0006	–0.0003
	Sex (Woman)*BDS	0.0071	0.0070	0.0070	0.0033	0.0113
	Age*log(education)	0.0081	0.0080	0.0075	0.0034	0.0123

Note: *Interaction; BDS = Bilingual Dominance Scale; HDI = Highest Density Intervals.

3.5. Boston Naming Test (BNT)

Education was related to the BNT total score, such that scores increased according to the natural logarithmic transformation of education. In addition, an interaction between education by BAS and education by BDS were found, such that people with higher Hispanic acculturation and greater Spanish proficiency obtained higher scores than those with lower Hispanic acculturation and greater English proficiency. Moreover, performance increased with greater years of education (Table 4 and Fig. 2C, D).

3.6. Normative procedure

An expanded explanation of the procedure can be found in Rivera et al. (2024). Briefly, norms (e.g., a percentile score) for the verbal fluency and BNT scores were established using a four-step procedure: 1) The expected test score ($\hat{\mu}_i$) was computed based on the parameters estimates from the established regression model $(\hat{\beta}_p)$, using:

$$\hat{\mu}_i = e^{\hat{\beta}_0} \cdot e^{\hat{\beta}_1 X_i^{(1)}} \cdot \ldots \cdot e^{\hat{\beta}_p X_i^{(p)}}$$

and

$$\hat{\pi}_j = \frac{\exp\left(\hat{\beta}_0 + \hat{\beta}_1 X_j^{(1)} + \hat{\beta}_p X_j^{(p)}\right)}{1 + \exp\left(\hat{\beta}_0 + \hat{\beta}_1 X_j^{(1)} + \hat{\beta}_p X_j^{(p)}\right)}.$$

Bear in mind that demographic variables were multiplied by 3000 samples of parameters. 2) The probability based on the Poisson/Binomial Cumulative Distribution Function was estimated for each of the 3000 sample parameters, 3) a mean probability was calculated, and 4) this probability was multiplied by 100 to interpret it as a percentile.

3.7. User-friendly normative data

To facilitate the understanding of the procedure to obtain the percentile associated with a given score on this test, an example will be given. Suppose you need to find the probability for a woman, who is 50 years old and has 15 years of education. She obtained a BDS score of 10 and a score of 8 on the /f/ phoneme.

Since the method explained above is complex and can be prone to human error due to the number of required computations, we have created an online calculator based on https://www.rstudio.com/products/shiny/. This will facilitate probability calculation as clinicians should only include patient information requested in the calculator (i.e., gross score for the specific test, age, education, and so on). This tool is available for all users at https://neuropsychologylearning.com/datos-normativos-archivos-descargables/. Using the calculator and introducing the information requested, this woman would obtain

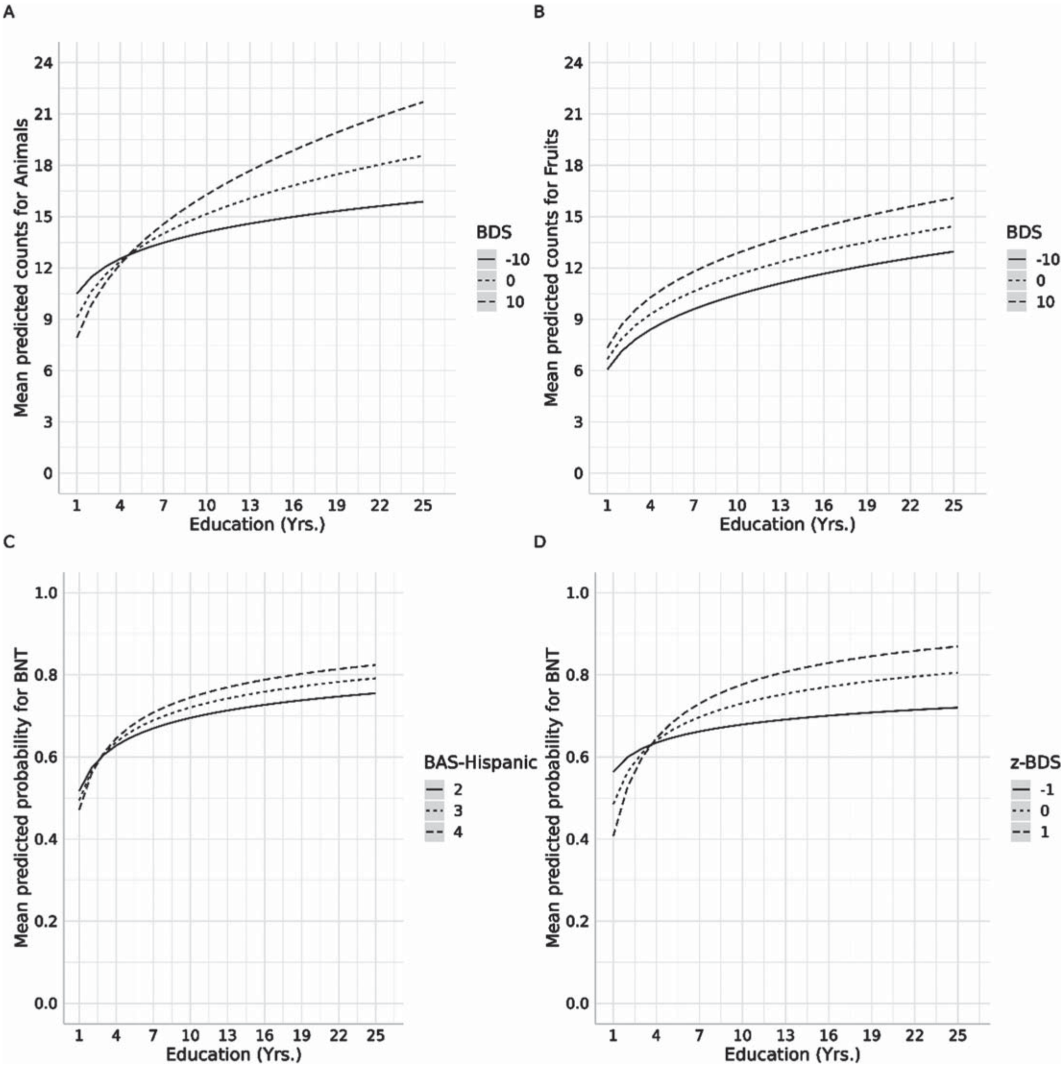

Fig. 2. Predicted mean score as a function of demographic variable included in the semantic verbal fluency and BNT models. *Note:* BAS = Bidimensional Acculturation Scale for Hispanics; z-BDS = Bilingual Dominance Scale – rescaling to z distribution.

a mean probability score of .245, that is, at the 24.5th percentile.

4. Discussion

The purpose of the study was to develop normative data for the phonological and semantic verbal fluency tests as well as the BNT among Spanish-speaking adults residing in the U.S. It was the first known study to control for the effect of both sociodemographic and Hispanic acculturation variables on test performance where appropriate. Across different phonemes, semantic categories, and the BNT, age, education, and sex exhibited several main effects. However, these effects were often qualified by interactions with time spent in the U.S., Hispanic cultural identity, and Spanish proficiency.

In the current study, while sex did not emerge as a meaningful independent predictor of verbal fluency or BNT test scores, sex interacted with Spanish proficiency, such that Spanish proficiency was more strongly associated with higher scores on many of the phonological verbal fluency measures in women compared to men. Thus, sex was included in the models to establish norms based on the interaction between sex and other key predictors such as Spanish proficiency. The impact of sex on language measures has been variable and inconclusive; in many previous studies, sex did not significantly impact verbal

Table 4
Mean, median, mode, and credibility interval (95%) for the posterior distributions of the parameters in the semantic verbal fluency and Boston Naming Test models

Test score	Parameters	Mean	Median	Mode	HDI Low	HDI High
Animals	Intercept	2.1931	2.2003	2.2199	1.7833	2.6111
	log(education)	0.2267	0.225	0.219	0.0799	0.3782
	BDS	–0.0132	–0.0134	–0.0133	–0.0368	0.0105
	log(education)*BDS	0.0089	0.0089	0.0087	5.00×10^{-4}	0.018
Fruits	Intercept	1.8868	1.8857	1.8779	1.45	2.3161
	log(education)	0.2438	0.244	0.239	0.0723	0.3921
	BDS	0.0098	0.0096	0.0082	–0.0157	0.0342
	log(education)*BDS	3.00×10^{-4}	4.00×10^{-4}	0.0012	–0.0091	0.009
BNT	Intercept	0.2112	0.2989	0.3079	–2.0554	1.8876
	log(education)	0.1599	0.1226	0.1026	–0.4931	0.9815
	BAS-Hispanic	–0.0792	–0.106	–0.0805	–0.6112	0.5394
	z-BDS	–0.319	–0.3171	–0.3315	–0.6547	0.0281
	log(education)*BAS-Hispanic	0.0879	0.0994	0.103	–0.1491	0.2818
	log(education)*z-BDS	0.2464	0.2451	0.2412	0.1143	0.369

Note: *Interaction; BAS = Bidimensional Acculturation Scale for Hispanics; BDS = Bilingual Dominance Scale; HDI = Highest Density Intervals; z-BDS = Bilingual Dominance Scale – rescaling to z distribution; BNT = Boston Naming Test.

fluency test scores (Marquine et al., 2021; Menon et al., 2012; Peña-Casanova et al., 2009a). The findings from the current study suggest that this might have been because other key acculturative moderators of the effect of sex were not considered.

The effects of education on test performance found in the current study were generally in line with previous studies; higher scores on many of the verbal fluency measures and the BNT were observed for those with higher educational attainment. Additionally, several significant interactions were found based on education's interaction with other key predictors such as Spanish proficiency. Prior literature has similarly found that individuals with higher education levels have better performance on verbal fluency tasks (Lubrini et al., 2022; Strauss et al., 2006) and the BNT (Neils et al., 1995; Zec et al., 2007), and that language proficiency impacts phonological and semantic fluency test performance (Friesen et al., 2015; Kastenbaum et al., 2019). One interesting finding in the current study was the interaction effect between education and Spanish language proficiency for the /f/ phoneme, animals, fruits, and the BNT, such that higher education had a stronger effect on performance among individuals with higher Spanish proficiency. Thus, the current study not only generated education-adjusted norms but did so in the context of participants' Spanish language proficiency.

While previous studies have found lower verbal fluency scores with older age (Boone et al., 2007; Peña-Casanova et al., 2009b), the current study demonstrated the differential effect of age on verbal fluency test scores as a function of education. Older age was more strongly associated with increased verbal fluency among people with higher education levels across phonemes /p/ and /r/. Also, the effect of age on phoneme /p/ performance was positive for men but negative for women. Thus, age was included in the models to establish norms based on the interaction between age and other key predictors such as education and gender.

Interestingly, some interactions were found between time in the U.S. and other variables such as Hispanic acculturation. For example, the effect of time in the U.S. on phoneme /s/ performance was negative for individuals with a higher Hispanic acculturation level but positive for those with lower Hispanic acculturation levels. As a result, while time in the U.S. is an important covariate in neuropsychological testing for these Spanish speakers, it must be qualified on different verbal fluency tasks by other important demographic and acculturative variables.

4.1. Clinical implications

This study has important implications for neuropsychology practice and research. The norms provided may help clinicians and researchers improve accurate identification of neurocognitive impairments relating to phonological and semantic verbal fluency and word naming among Spanish-speaking adults in the U.S., facilitating appropriate treatment selection. The findings have also demonstrated the importance of generating normative data on language measures for dominant Spanish speakers in the U.S., since social, cultural, and linguistic differences have been shown in the current study and past research (e.g. Mungas et al., 2005) to impact neuropsychological test performance. In order to utilize these norms, the BDS and BAS must be administered to capture acculturation and bilingual dominance, two factors that are important when working with the diverse population of dominant Spanish speakers in the U.S. It is also important to note that the use of phonemes differs somewhat from letter fluency because the instructions here were designed to elicit words that begin with a sound rather than a letter. This is a small but important distinction that may be useful for individuals with low education or literacy (Olabarrieta-Landa et al., 2017). The effects of sociocultural variables on traditional demographic variables should be examined in future norming efforts for immigrant populations.

4.2. Limitations and future directions

The current study had several limitations that present opportunities for future research. First, the mean years of education in the current sample was more than 12 years, which may limit the generalizability of the norms for individuals with lower levels of education. Additionally, this study only included neurologically healthy adults, highlighting the gap for future research to establish normative data with pediatric populations or adults with neurological and/or psychiatric illnesses. Second, while this study examined the effects of language proficiency on phonemic fluency test scores, the BDS is a subjective measure of language dominance that relies on individuals' memory and perception of their own linguistic proficiency and language use. Since self-ratings are prone to bias, future research may consider using objective measures to assess bilingualism (Gollan et al., 2024). Finally, the current norms may only be used when the individual is fluent in Spanish and resides in the U.S., whereas the application of these norms to Spanish-speaking individuals outside of the U.S. would increase the risk of misdiagnosis.

5. Conclusion

The present study addressed the urgent need to develop neuropsychological testing norms for phonological and semantic verbal fluency tests as well as the BNT among dominant Spanish-speaking adults in the U.S., while uniquely incorporating the impact of immigration variables on test performance. To date, this is one of the first studies that has examined how sociocultural factors may influence test scores on language measures and established norms that were adjusted based on the interaction effects of traditional demographic variables (age, gender, education) and immigration variables (Spanish proficiency, level of acculturation, time in the U.S.). Overall, the use of group-specific, sociodemographically-adjusted norms is supported to improve the clinical utility of language measures in neuropsychological assessments for Spanish-speaking immigrant populations in the U.S.

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Declaration of interest

The authors have no conflicts of interest to declare.

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