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Estimating Intelligence in Spanish: Regression Equations With the Word Accentuation Test and Demographic Variables in Latin America

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Spanish is the fourth most spoken language in the world, and the majority of Spanish speakers have a Latin American origin. Reading aloud infrequently accentuated words has been established as a National Adult Reading Test-like method to assess premorbid intelligence in Spanish. However, several versions have been proposed and validated with small and selected samples, in particular geographical conditions, and they seldom derive a formula for IQ estimation with the Wechsler Adult Intelligence Scale (WAIS) Full-Scale IQ (FSIQ). The objective of this study was to develop equations to estimate WAIS-Third Edition (WAIS-III) FSIQ from the Word Accentuation Test-Revised (WAT-R), demographic variables, and their combination within diverse Latin American samples. Two hundred and forty participants from Argentina and Colombia, selected according to age and years of education strata, were assessed with the WAT-R, the WAIS-III, and a structured questionnaire about demographic and medical information. A combined approach including place of birth, years of education, and WAT-R provided the best equation, explaining 76% of IQ variance. These equations could be useful for estimating premorbid IQ in patients with Latin American Spanish as their birth language.

Key words: *intelligence estimation, premorbid intelligence, Spanish, Word Accentuation Test*

INTRODUCTION

Accurate estimation of premorbid intelligence is a key factor in neuropsychological research and practice, as an aid for the interpretation of changes in ability and as a control variable. One approach is to estimate intelligence on the basis of stable predictors such as demographic variables not affected by injury and correlated with IQ performance: age, gender, race, years of education, occupation, and cultural context (Ardila, 1996; Ardila, Rosselli, & Puente, 1994; Barona, Reynolds, & Chastain, 1984; Bilbao-Bilbao & Seisdedos, 2004). Different equations have been derived with the Wechsler Adult Intelligence Scale (WAIS; Wilson et al., 1978), WAIS-Revised (Barona et al., 1984; Bilbao-Bilbao & Seisdedos, 2004; Crawford & Allan, 1997), and WAIS-Third Edition (WAIS-III; The Psychological Corporation, 2001), explaining 36% (The Psychological Corporation, 2001) to 60% (Barona et al., 1984) of IQ variance.

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Regression equations with demographic variables and "hold" tests have shown an increment of variance explanation (Alves, Simoes, & Martins, 2012; Chen, Ho, Chen, Hsu, & Ryu, 2009; Crawford, Crochrane, Besson, Parker, & Stewart, 1990; Crawford, Nelson, Blackmore, Crochrane, & Allan, 1990; Krull, Scott, & Sherer, 1995; Schoenberg, Scott, Duff, & Adams, 2002; Vanderploeg & Schinka, 1995). The most popular "hold" tests are those based on reading of irregular words such as the National Adult Reading Test (NART; Nelson, 1982), its revised version (Berry et al., 1994), its adaptation in American English (Grober, Sliwinsk, & Korey, 1991), and the Hopkins Adult Reading Test (Schretlen et al., 2009). These tests have shown high correlations with IQ in normal participants (Crawford, Stewart, Cochrane, Parker, & Bensson, 1989; Schretlen, Buffington, Meyer, & Pearlson, 2005) and no significant change in prodromal and initial phases of a neurodegenerative disease (Carlozzi et al., 2011), mild and mild-to-moderate dementia (Bright, Jaldow, & Kopelman, 2002; Deary, Whally, & Crawford, 2004; Fromm, Holland, Nebes, & Oakley, 1991; Maddrey, Cullum, Weiner, & Filley, 1996; Matsuoka, Uno, Kasai, Koyama, & Kim, 2006; McGurn et al., 2004; Sharpe & O'Carroll, 1991), traumatic brain injury (Crawford, Besson & Parker, 1988; Green et al., 2008; Moss & Dowd, 1991; Watt & O'Carroll, 1999), and psychiatric disorders (Crawford, Besson, Parker, Sutherland, & Keen, 1987; O'Carroll et al., 1992). Although there is evidence of change in long-term medicated schizophrenia (Russell et al., 2000) and dementia with initial language deficits (Paque & Warrington, 1995; Stebbins, Gilley, Wilson, Bernard, & Fox, 1990), these correspond to stages in long-term deteriorating diseases in which language is affected; most other studies have shown the stability of performance in spite of other deficits. Reading aloud irregular words as an approach to IQ estimation has become so much a "gold standard" that the Wechsler battery has conormed a 50-item version (Wechsler Test of Adult Reading [WTAR]; Wechsler, 2001b).

The rationale behind these tests relies on the fact that English is an opaque language, with highly irregular rules for pronunciation of printed words. On the other hand, in transparent languages such as Spanish, the grapheme–phoneme correspondence is very consistent, and any written word or nonword can be read aloud generating the sounds from letters (Carreiras, Albea, & Sebastián-Gallés, 1996; Signorini, García, & Borzone, 2000). Accentuation is also quite regular. The words that do not follow accentuation rules must be orthographically stressed. There are exceptions; and for the correct accentuation of irregularly accentuated words, the reader needs to see the written accentuation mark or have previous knowledge of the correct accentuation of the word when this mark is not present. Based on this accentuation source of irregularities, Del Ser and coworkers (Del Ser, González-Montalvo, Martínez-Espinosa, Delgado-Villapalos, & Bermejo, 1997) developed a Spanish version of the NART, the Word Accentuation Test (WAT). Thirty low-frequency words with irregular accentuation, printed in uppercase letters without their graphic accents, have to be read aloud. In a sample of 81 normal older adults from Madrid, Spain, this task exhibited high reliability, high and significant correlations with WAIS Vocabulary and Picture Completion tests, and lower but significant correlations with the Raven Progressive Matrices and Mini Mental State Examination. Also in Spain, Gomar et al. (2011) calculated a formula for converting the WAT score into a prorated WAIS-III Full-Scale IQ (FSIQ) score (from five subtests, including Vocabulary, Similarities, Matrix Reasoning, Block Design, and Digit Span) in 96 European Spanish-speaking normal participants. The WAT explained 56% of IQ variance.

Spanish is the fourth most spoken native language in the world; it is the official language in 19 Latin American countries, Spain, and Equatorial Guinea, so most Spanish speakers have a Latin American origin (Instituto Cervantes, 2012). Also, most Spanish-speaking immigrants in the United States come from Latin America. Given that Spanish has regional differences, especially in lexical knowledge, and that the original WAT was derived with a small European Spanish sample, Burin, Jorge, Arizaga, and Paulsen (2000) developed a South American WAT version in Buenos Aires, Argentina (WAT-BA). Twenty-one items of the original Spanish version remained in the WAT-BA. In a sample of 74 normal older adults, the WAT-BA showed high loading (.81) to a crystallized intelligence factor and low correlations with a delayed memory factor and a speed/executive factor. In the United States, Krueger, Lam, and Wilson (2006) developed a 40-item version, the WAT-Chicago for immigrant Spanish speakers. The validation sample included 45 adults aged 29 to 73 years old, who were mainly from Mexico and Puerto Rico and whose years of education ranged from 0 to 18. Their mean IQ was 95 ($SD = 16$), as assessed with the Spanish adaptation of the WAIS-III (Wechsler, 2001a). To choose which words to include, they administered both the Spanish and the Argentinian WAT versions. After item analyses, they retained 40 words; consistent with the results from Burin et al. (2000), they found that more than one fifth of the words from the original Spanish test needed to be discarded. Within this sample ($n = 45$), they derived a regression equation with WAT-Chicago, education, and age estimating FSIQ. In the same vein, Schrauf, Weintraub, and Navarro (2006) also sought to validate a word accentuation test for older Spanish-speaking U.S. immigrants. The sample included 80 older Spanish speakers aged 13 and 80 years old who had immigrated to the United States, mainly from Mexico (51%) and Puerto Rico (16%). The researchers administered the original WAT items, plus 55 polysyllabic new words according to the criteria of "rare in the corpus and accented" (Schrauf et al., 2006, p. 393). They found that the Comprehensive Knowledge index from the Woodcock-Muñoz-R battery (a vocabulary measure) showed correlations of a similar magnitude both with the original WAT ($r^2 = .77$) and with a modified, 31-item version of the WAT retaining only 12 items from the original ($r^2 = .73$). Thus, they argued that it was not necessary to change the word list. However, a limitation regarding this study concerns the finding that education was not significantly correlated with the WAT; this finding was attributed to range restriction in the number of years of formal education ($M = 8.5$, $SD = 4.2$).

In summary, estimating intelligence in Spanish with the demographic + read-aloud method has been shown to be feasible. Correctly reading aloud infrequently accentuated words has been established as a NART-like method. However, several versions have been proposed and validated with small and selected samples, in particular geographical conditions, and they seldom derive a formula for IQ estimation with the WAIS FSIQ. Therefore, the objective of this study was to develop regression equations to estimate the WAIS-III IQ from the WAT–Revised (WAT-R), demographic variables, and their combination in two geographically diverse South American samples of community-dwelling adults, representative of age and educational-level quotas.

Following historical processes and economic and cultural similarities, South America has two main regional organizations: the Andean Pact (Northeast countries, including Colombia, Bolivia, Ecuador, and Peru) and Mercosur (Center-South countries, including Argentina, Brazil, Uruguay, and Paraguay). Argentina and Colombia are the most populated Spanish-speaking countries in each regional organization (Bay & Macadar, 2003). Thus, two subsamples from each of these countries were included in the study.

Based on previous regression results in premorbid intelligence, we predicted that a combined approach with the WAT-R and demographic variables such as region of precedence, years of education, and occupation would explain a high and significant percentage of IQ.

Because previous research has employed small and limited samples, deriving IQ estimates from a large and representative sample would be an asset not only for clinical settings, but also for forensic and educational purposes.

METHOD

Participants

Two hundred and forty South American normal adults volunteered to participate in the study. South America has two main regional organizations, the Andean Pact and Mercosur; Colombia and Argentina have the largest Spanish-speaking populations in each of these regions, respectively. Following these criteria, two subsamples ($n = 120$, 60 female participants and 60 male participants in each) were recruited in Colombia and Argentina. Each participant was screened for the following exclusion criteria: (a) diagnosed neurologic or psychiatric disease affecting cognitive function (stroke, electroconvulsive treatment, epilepsy, brain injury, encephalitis, meningitis, multiple sclerosis, Parkinson disease dementia, Huntington chorea, Alzheimer-type dementia, schizophrenia, bipolar disorder, or actually being medicated with antidepressive or antipsychotic medication); (b) first language other than Spanish; (c) visual or auditory impairment not compensated; (d) heavy alcohol consumption, as defined by more than three alcoholic beverages more than 2 days a week; (e) adult episode of loss of consciousness for more than 5 min; and (f) adult episode of cranioencephalic trauma with hospitalization.

The inclusion criteria were defined by quota criteria as shown in Table 1: (a) age 20 to 74 years old, (b) birth and residence in one of the two South American regions, and (c) age and years of education brackets. Education Level I refers to complete or incomplete basic elementary school; Education Level II refers to complete or incomplete high school or secondary school; Education Level III refers to formal college education after completing secondary school.

TABLE 1
Quota Criteria for Participants' Selection, by Gender, Age, Years of Education, and Place of Birth

	Education Level					
	I		*II*		*III*	
Age	*Colombia*	*Argentina*	*Colombia*	*Argentina*	*Colombia*	*Argentina*
20–34 years	8 (4 women, 4 men)	8 (4 women, 4 men)	8 (4 women, 4 men)	8 (4 women, 4 men)	8 (4 women, 4 men)	8 (4 women, 4 men)
35–44 years	8 (4 women, 4 men)	8 (4 women, 4 men)	8 (4 women, 4 men)	8 (4 women, 4 men)	8 (4 women, 4 men)	8 (4 women, 4 men)
45–54 years	8 (4 women, 4 men)	8 (4 women, 4 men)	8 (4 women, 4 men)	8 (4 women, 4 men)	8 (4 women, 4 men)	8 (4 women, 4 men)
55–64 years	8 (4 women, 4 men)	8 (4 women, 4 men)	8 (4 women, 4 men)	8 (4 women, 4 men)	8 (4 women, 4 men)	8 (4 women, 4 men)
65–74 years	8 (4 women, 4 men)	8 (4 women, 4 men)	8 (4 women, 4 men)	8 (4 women, 4 men)	8 (4 women, 4 men)	8 (4 women, 4 men)

Materials

Participants completed:

- A semistructured interview concerning demographic variables (age, years of education, place of birth, and occupation) and medical history. Occupations were codified as an ordinal variable following the Crawford and Allan (1997) categories. Based on these categories, the Colombian sample was composed of 20 professionals and 24 intermediate, 23 skilled, 19 semiskilled, and 34 unskilled participants. The Argentinian sample was composed of 27 professionals and 24 intermediate, 9 skilled, 39 semiskilled, and 21 unskilled participants.
- The WAIS-III (Wechsler, 2002)
- The WAT-R. The WAT-R (Appendix) included the 44 words from the WAT-BA and 6 additional low-frequency words (below 23/2,000,000 according to Alameda & Cuetos, 1995). Instructions, examples, and scoring follow the WAT-BA version (Burin et al., 2000).

Procedure

Participants were recruited from health facilities and community centers and were invited to an evaluation of their general intelligence. Participants were informed about the confidentiality of the information to collect and they participated voluntarily. Consent was obtained.

Two psychologists, specialized in clinical neuropsychology, performed the interview and assessment. Participants were assessed individually in a 2-hr session, and 1 week later, they were informed about their performance on the WAIS-III.

The research protocol was approved by the National Scientific and Technical Research Council (CONICET) in Argentina.

RESULTS

Descriptive statistics of the sample are shown in Table 2. Internal consistency of the WAT-R was calculated with Cronbach's $\alpha = .95$.

TABLE 2
Sample Descriptions

	Mean (SD)	*Minimum*	*Maximum*
Age (years)	49.1 (14.9)	20	74
Years of formal education	10.55 (5.3)	1	24
WAT-R	32.5 (11.3)	7	50
IQ	86.9 (17.8)	56	144

WAT-R = Word Accentuation Test-Revised.

The IQ score mean was around 1 standard deviation below what was expected (Wechsler, 2002); this could reflect the higher number (two thirds of the sample) of participants with less than 12 years of education compared with the WAIS-III norming sample (one third of the sample; Tulsky & Ledbetter, 2000). Heaton, Taylor, and Manley (2003) reported that 15% to 25% of participants with less than 12 years of education will obtain a low or impaired IQ using the WAIS-III norms. When the IQ mean and standard deviation are calculated in the sample with more than 11 years of education, the IQ score is normalized ($M = 102.9$, $SD = 13.5$).

The correlations between IQ, the WAT-R, and numerical demographic variables were performed to identify the variables that should be used as independent variables in the linear regressions to estimate IQ. The WAT-R had a high ($r = .82$) and significant ($p < .001$) correlation with the WAIS FSIQ. Indeed high and significant correlations were found between WAIS IQ and years of education ($r = .78$, $p < .001$), and low and nonsignificant correlations were found between the WAIS IQ and age ($r = .05$, $p = .46$). To identify the non-numerical demographic variables that should be used as independent variables in the linear regressions to estimate IQ, one-way analysis of variance and t test were performed. There were significant differences in WAIS IQ by occupation, $F(4, 239) = 36.34$, $p < .001$, and by place of birth, $t(238) = -4.31$, $p < .001$, but not by gender, $t(238) = -1.19$, $p = .24$. These results suggest that the WAT-R, years of education, occupation, and place of birth could be entered as independent variables in the linear regressions to estimate WAIS IQ.

Given the objective of the study, to derive formulas for IQ estimation, regression equations were performed, with demographic variables and the WAT-R as predictors and IQ as criteria. A series of linear regression equations through hierarchical selection with WAIS IQ as the dependent variable were generated: WAT-R as predictor (Regression 1, WAT-R regression); place of birth, age, gender, years of education, and occupation as predictors (Regression 2, demographic regression); and years of education, place of birth, occupation, and WAT-R as predictors (Regression 3, combined regression).

The three hierarchical regression analyses were completed using the target IQ score as the dependent variable and demographic variables and WAT-R score as the independent measures. For the demographic regression and combined regression, each of the five demographic variables (age, gender, region of South America, years of education, and occupation) were entered into the regression in five subsequent steps. Age in years and years of education were entered as a continuous variable. Region of South America, gender, and occupation were each entered into the regression as a set of dummy-coded variables. The significance of each demographic variable was tested over and above all other variables on the final step of the hierarchy using R^2 change statistics. Any demographic variable that did not add significantly ($p < .05$) to the estimation of IQ scores in the final step was excluded from the equation. When one or more demographic variables were excluded during this first stage of equation building, the process was repeated using the remaining demographic variables until all remaining demographic variables contributed significantly to the regression equation.

In Regression 1 (Table 3), only WAT-R was entered as a predictor. WAT-R significantly accounted for 68% of WAIS IQ variance ($R^2 = .68$, $t = 22.43$; $p < .001$).

To identify if the size of residual with Regression 1 was related to levels of IQ, a correlation between IQ and the size of the residual was performed. The IQ showed a high and significant correlation with the size of the residual ($r = .57$, $p < .001$). To investigate if the relation was similar in different IQ levels, the data were segmented in participants with low IQ (IQ < 85), average IQ ($85 \leq$ IQ ≤ 115), and high IQ (IQ > 115), and correlations were performed between the different IQ levels and the size of the residual. There was a high and significant correlation with the size of the residual in participants with average IQ ($r = .54$, $p < .001$) and high IQ ($r = .87$, $p < .001$), but not in participants with low IQ ($r = .09$, $p = .36$). These results show that the error size of the prediction of Regression 1 was related to the average and high IQ levels and not to low IQ levels. The mean of the residual for participants with average IQ was 1.2 ($SD = 7.4$), and the mean residual for participants with high IQ was 20.5 ($SD = 8.2$). The conversion of the WAT-R score to estimated WAIS IQ is shown in Table 4.

In Regression 2 (Table 5), demographic variables were entered as predictors. A hierarchical regression with age, place of birth (dummy coded), years of formal education, occupation (dummy coded), and sex (dummy coded) as predictors was performed. Place of birth and years of education explained 63% of WAIS IQ variance significantly, F(6, 237) = 204.084, $p < .000$. The tolerance value and variance inflation factor (VIF <10; tolerance $>.01$) suggest no collinearity between years of education and place of birth.

TABLE 4
Conversion of WAT-R Score to WAIS IQ Scores

WAT-R Score	*Predicted WAIS IQ*	*WAT-R Score*	*Predicted WAIS IQ*
1	46	25	77
2	47	26	78
3	49	27	80
4	50	28	81
5	51	29	82
6	53	30	84
7	54	31	85
8	55	32	86
9	56	33	88
10	58	34	89
11	59	35	90
12	60	36	91
13	62	37	93
14	63	38	94
15	64	39	95
16	65	40	97
17	67	41	98
18	68	42	99
19	69	43	101
20	71	44	102
21	72	45	103
22	73	46	104
23	75	47	106
24	76	48	107
25	77	49	108
		50	110

WAIS = Wechsler Adult Intelligence Scale; WAT-R = Word Accentuation Test-Revised.

To identify if the size of the residual with Regression 2 was related to levels of IQ, a correlation between IQ and the size of the residual was performed. IQ showed a high and significant correlation with the residual size ($r = .60$, $p < .001$). To investigate if the relation was similar in different IQ levels, the data were segmented by IQ: low IQ (IQ < 85), average IQ ($85 \leq$ IQ ≤ 115), and high IQ (IQ > 115). There was a moderate and significant correlation with residual size in participants with low IQ ($r = .32$, $p < .001$) and a high and significant correlation in participants with high IQ ($r = .78$, $p < .001$), but no correlation with participants in the average range ($r = .09$, $p = .309$). These results show that the error size of the prediction of Regression 2 was related to the low and high IQ levels and not to average IQ levels. The mean of the residual for participants with low IQ was

TABLE 3
Linear Regression 1: WAIS IQ as a Function of the WAT-R

Model	*B*	*Std. Error*	*Beta*	*t*	*p Value*	*Std. Error Estimate*	R^2
1 (constant)	44.726	1.989		22.484	<.000		
WAT-R	1.298	0.058	.824	22.433	<.000	10.11	.68

WAIS = Wechsler Adult Intelligence Scale; WAT-R = Word Accentuation Test-Revised.

TABLE 5
Linear Regression 2: WAIS IQ as a Function of Place of Birth and Years of Education

Model	*B*	*Std. Error*	*Beta*	*t*	*p Value*	*Std. Error Estimate*	*Change in R^2*
1 (constant)	57.181	1.642		34.82	<.000		
Place of birth	5.905	1.412	.166	4.18	<.000	17.185	.072
Years of education	2.534	0.133	.756	19.01	<.000	10.837	.560

WAIS = Wechsler Adult Intelligence Scale.

−5.4 ($SD = 8.7$), and the mean residual for participants with high IQ was 19.82 ($SD = 10$).

The equation for IQ estimate based on the demographic regression is:

WAIS IQ = 57.181 + (5.905 × place of birth) + (2.534× years of education)
Place of birth: north of South America = 0; south of South America = 1

In Regression 3 (Table 6), the combined approach with the WAT-R and demographic variables was performed. The regression equation entered place of birth, years of formal education, and WAT-R as predictors for WAIS IQ. Place of birth, years of education, and WAT-R explained 76% of WAIS IQ variance. The predictors significantly explained WAIS IQ, $F(3, 236) = 248.238$, $p < .000$. The tolerance value and VIF (VIF <10; tolerance >.01) suggest no collinearity between place of birth, years of education, and the WAT-R.

To identify if the size of the residual with Regression 3 was related to levels of IQ, a correlation between IQ and the size of the residual was performed. IQ showed significant correlation with the size of residuals ($r = .49$, $p < .001$). To investigate if the relation was similar in different IQ levels, the data were segmented into participants with low IQ (IQ < 85), average IQ (85 ≤ IQ ≤ 115), and high IQ (IQ > 115). There were no significant correlations with the size of residuals in participants with average IQ ($r = .27$, $p = .004$) and low IQ ($r = .11$, $p = .24$). In participants with high IQ, there was a high and significant correlation with the residual size ($r = .84$, $p < .001$; $x = 17.19$, $SD = 8.92$). These results show that the error size of the prediction of Regression 3 was related to high IQ levels and not to low and average IQ levels.

The equation for the IQ estimate based on the combined regressions is:

WAIS IQ = 44.439 + (4.418 × place of birth) + (1.257× years of education) + (0.83 × WAT-R)
Place of birth: north of South America = 0; south of South America = 1

Pearson r correlations between real IQ and estimated IQ with the WAT-R regression equation ($r = .82$, $p < .001$), demographic variables ($r = .79$, $p < .001$), and WAT-R-plus-demographic variables ($r = .87$, $p < .001$) were high and significant, reflecting minimal "shrinkage" of predictive accuracy.

These regressions yielded standard errors of the estimate of 8.69 points for the WAT-R only, 10.837 points for demographic variables only and 8.979 points for the WAT-R-plus-demographic variables, respectively. We next applied these equations and stratified the differences in actual IQ minus the predicted IQ into three discrete ranges. The percentage of individuals who fell into each discrepancy range based on the WAT-R, demographic, and WAT-R-plus-demographic equations are shown in Table 7. McNemar's test of paired proportions was used to compare the predictive accuracy of the three models. The WAT-R-plus-demographics model had a better predictive accuracy than the demographic variables model ($p < .001$) and WAT-R model ($p < .001$).

The percentage of cases correctly classified in their IQ category based on the WAT-R, demographic, and WAT-R-plus-demographic equations are shown in Table 8. The best model to identify the extremely low IQ was the WAT-R-plus-demographic model. This model identified an equal proportion of low, average, and high IQ participants compared with the WAT-R-only and demographic-only models. Chi-square analysis revealed

TABLE 6
Regression 3: WAIS IQ as a Function of Place of Birth, Years of Education, Occupation, and WAT-R

Model	*B*	*Std. Error*	*Beta*	*t*	*p Value*	*Std. Error Estimate*	*Change in R^2*
1 (constant)	44.439	1.755		25.32	<.000		
Place of birth	4.418	1.182	.122	3.68	<.000	17.185	.072
Years of education	1.257	0.158	.375	7.98	<.000	10.837	.560
WAT-R	0.830	0.074	.527	11.15	<.000	8.979	.127

WAIS = Wechsler Adult Intelligence Scale; WAT-R = Word Accentuation Test-Revised.

TABLE 7
Predictive Accuracy of Estimated IQ Scores

Model	Percent Within ±5 Points	Percent Within ±10 Points	Percent Within Same Category[a]
WAT-R	47.1	71.2	71.2
Demographic variables	35.8	67.9	59.6
Demographic variables plus WAT-R	51.7	81.7	71.2

WAT-R = Word Accentuation Test-Revised.
[a]Category: extremely low (IQ < 70), low average (69 < IQ < 85), average (84 < IQ < 115), high (IQ > 114).

TABLE 8
Percent Correctly Identified in Each IQ Category

IQ Category[a]	WAT-R Model	Demographic Variables Model	Demographic Variables Plus WAT-R Model
Extremely low	65.1	34.9	72.1
Low average	60.4	17.1	60.4
Average	90.9	77.3	86.4
High	0	12.5	12.5

WAT-R = Word Accentuation Test-Revised.
[a]Category: extremely low (IQ < 70), low average (69 < IQ < 85), average (84 < IQ < 115), high (IQ > 114).

that the predictive accuracy of the combined model is better in all IQ ranges—extremely low ($p < .001$), low-average ($p < .000$), average ($p < .000$), and high average ($p < .001$)—compared with the WAT-R model and demographic model. The WAT-R model has a higher predictive accuracy in the low ($p < .001$) and average ($p < .004$) ranges than does the demographic-variables model. The two models are similar in predictive accuracy for the extremely low range ($p = .38$).

DISCUSSION

The general objective of this study was to develop equations to estimate IQ in a representative sample of two Latin American Spanish-speaking regions. A "hold" test—the WAT-R—demographic variables, and their combination were compared.

The WAT-R showed a high internal consistency (.95), as has been published in similar English (Nelson, 1982; Nelson & Willison, 1991) and Spanish tests (Burin et al., 2000; Del Ser et al., 1997; Krueger et al., 2006; Schrauf et al., 2006). There were high and significant correlations between the WAT-R and IQ, showing convergent validity as has been found for similar tests (Crawford, Stewart, Cochrane, Parker, et al., 1989; Lowe & Rogers, 2011; Schretlen et al., 2005) and previous WAT versions (Del Ser et al., 1997; Krueger et al., 2006; Schrauf et al., 2006). The WAIS IQ had high and significant correlations with the WAT-R and years of education and showed differences as a function of different occupational levels and place of birth. This pattern adds to the WAT-R's construct validity. Also, this pattern suggests that the WAT-R, place of birth, years of education, and occupation are related to IQ and can be used for its prediction.

The linear regression from demographic variables in this study showed that occupation did not increase the variance explanation when years of education were also entered. Previous formulas with demographic variables in Spanish-speaking samples (Bilbao-Bilbao & Seisdedos, 2004; Krueger et al., 2006) have not used occupation as a predictor. As other researchers have suggested, years of education could function as an estimate of occupation level (Vanderploeg & Schinka, 1995). Future studies should also examine the impact of occupation in the regression equations by including large systematic samples of various occupations. Also, regional place of birth added to the prediction—a result convergent with the findings of Bilbao-Bilbao and Seisdedos (2004), but in their case, regions represented areas of Spain and not Latin America. The importance of place of birth in the prediction of WAIS IQ performance would reflect sociocultural and economic differences between regions, as has been proposed by some researchers (Ardila et al., 1994).

Equations from demographic variables in Anglo-Saxon samples (Eppinger, Craig, Adams, & Parsons, 1987; Griffin, Rivera-Mint, Rankin, Ritchie, & Scott, 2002; Powell, Brossart, & Reynolds, 2003) had shown an overestimation in participants with low IQ and underestimation in participants with high IQ. Our analysis of residuals according to IQ range (low, average, high) was consistent with previous research. For example, for participants with an IQ higher than 1 standard deviation above the mean, the equation could underestimate about 16 points of their real IQ.

Regression employing only the WAT-R as a predictor explained 68% of IQ variance, as has been published recently in a similar test in Portuguese (Alves et al., 2012) and Spanish (Gomar et al., 2011). However, results showed a high relation between the prediction error size in the WAT-R equation and IQ; particularly in participants with high IQ, the equation could underestimate about 20 points of their real IQ.

Therefore, we derived a regression equation with place of birth, years of education, and the WAT-R to look for increases in IQ estimation. This combination explained 76% of the IQ variance, about 13% more than with demographic variables alone and about 8% more than with the WAT-R alone. This result contradicts other studies with smaller and/or more restricted samples (e.g., Schrauf et al., 2006) and converges with other studies (Crawford, Stewart, Parker, Besson, &

Cochrane, 1989), which found that the combination of variables explained around 70% of the variance. Indeed, a higher proportion of cases were around 10 points within the real IQ with the combined approach, compared with worse estimation with demographic variables and the WAT-R alone. In addition, the proportion of estimated IQ scores that were within 10 points of the actual IQ score based on the WAT-R (71.2%) and demographic variables plus the WAT-R (81.7%) in this study was similar to those in other studies (WTAR, 70.4%; WTAR and demographics, 73.4%; The Psychological Corporation, 2001).

Overall, this is the first study to derive regression equations for estimating premorbid intelligence in a large and representative Latin American sample. It provides a way to estimate IQ from information obtained quickly and reliably, such as years of education and performance on the WAT-R, which is a simple and fast test to implement in any setting. This research shows that IQ could be reliably estimated from the WAT-R and demographic variables in a large sample of normal adults. The equation recommended for use in clinical settings is:

$$\text{WAIS IQ} = 44.439 + (4.418 \times \text{place of birth}) + (1.257 \times \text{years of education}) + (0.83 \times \text{WAT-R})$$

Place of birth: north of South America = 0; south of South America = 1

To assess a tool or method to estimate premorbid intelligence, it should also demonstrate little or no impairment in brain injury. In this direction, Sierra, Torralva, Roca, Manes, and Burin (2010) found no significant differences in performance in the same test (WAT-R) between three groups: normal participants, participants with mild cognitive impairment, and participants with mild—to-moderate dementia, paired by age, sex, and years of school. However, there is no longitudinal research testing the stability of IQ estimation through the combined equation in brain injury. Future studies should estimate IQ scores with these equations in well-defined patient samples to assess their clinical utility as has been demonstrated in past research with similar equations to estimate premorbid IQ (Baade & Schoenberg, 2004; Del Ser et al., 1997; Gomar et al., 2011; Schoenberg, Duff, Scott, & Adams, 2003).

The WAIS-III is the most used intelligence battery in Latin American since it has been adapted to Argentinian (Wechsler, 2002) and Mexican populations (Tulsky & Zhu, 2003). A WAIS-Fourth Edition (WAIS-IV) Chilean version has been recently published (Rosas et al., 2014). The present equations should be further validated with the WAIS-IV Chile version or another future WAIS-IV validation in Spanish, in the case that they become standard.

Another limitation of the present study is the lack of inclusion of other Latin American regions—for example, those pertaining to the North American Free Trade Agreement. Future studies could replicate and expand our results with large and representative samples of different Latin American countries.

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APPENDIX

Stimuli of the Word Accentuation Test-Revised

MASTIN (Example)		
CANON	DIAMETRO	BULGARO
ACULLA	HELICOIDE	CELIBE
CONCAVO	DESCORTES	ISOTOPO
ALELI	POLIGAMO	TACTIL
SILICE	LAUDANO	ACME
ANOMALO	DISCOLO	PROCONSUL
SISTOLE	AMBAR	SUPERSTITE
BALADI	VOLATIL	PERONE
INVEROSIMIL	TORRIDO	RETRUECANO
ALEGORIA	ZAHORI	GRISU
NEOFITO	ACOLITO	LOBREGO
SANDALO	HIPERBOLE	GELIDO
INFULAS	APATRIDA	METROPOLI
HIPERBATON	ALBEDRIO	PECORA
PARONIMO	SALOBRE	PUGIL
ARCABUZ	MAYOLICA	GRAGEA
PRISTINO	TROPELIA	