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Concentration Endurance Test (d2): Normative data for Spanish-speaking pediatric population

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Abstract.
OBJECTIVE: To generate normative data for the Concentration Endurance Test (d2) in Spanish-speaking pediatric populations.
METHOD: The sample consisted of 4,373 healthy children from nine countries in Latin America (Chile, Cuba, Ecuador, Guatemala, Honduras, Mexico, Paraguay, Peru, and Puerto Rico) and Spain. Each participant was administered the d2 test as part of a larger neuropsychological battery. The Total number of items processed (TN), Total number of correct responses (CR), Total performance (TP), and Concentration performance (CP) scores were normed using multiple linear regressions and standard deviations of residual values. Age, age^2, sex, and mean level of parental education (MLPE) were included as predictors in the analyses.

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RESULTS: The final multiple linear regression models showed main effects for age on all scores, such that scores increased linearly as a function of age. TN scores were affected by age^2 for Guatemala and Puerto Rico; CR scores were affected by age^2 for Mexico; TP scores were affected by age^2 for Chile, Mexico, Puerto Rico, and Spain; and CP scores for Mexico and Spain. Models indicated that children whose parents had a MLPE >12 years obtained higher scores compared to children whose parents had a MLPE $\leq$12 years for Mexico and Spain in all scores, and Puerto Rico for TN, CR, and TP, and Guatemala and Paraguay for CP scores. Sex affect the scores for Ecuador and Honduras (CP scores).
CONCLUSIONS: This is the largest Spanish-speaking pediatric normative study in the world, and it will allow neuropsychologists from these countries to have a more accurate approach to interpret the d2 test in pediatric populations.

Keywords: Attention, Concentration Endurance Test (d2), neuropsychology, Spanish-speaking populations, pediatric population

1. Introduction

The term ‘attention’ refers to a multifaceted and multidimensional cognitive construct that includes sustained attention, selective attention, and inhibitory control (Lehman, Naglieri, & Aguilino, 2010). Prior research has demonstrated that up to 40% of children aged four years old already exhibit difficulties with attention to warrant teacher and parent concern (Palfrey, Levine, Walker, & Sullivan, 1985). Moreover, Attention Deficit Hyperactivity Disorder has emerged as one of the most common childhood conditions and one of the top reasons for neuropsychological referral (Sweet, Benson, Nelson, & Moberg, 2015). Given that attention plays a fundamental role in all cognitive, social, and emotional processes, impairments in these skills are associated with poor adaptive functioning, reduced quality of life, and a variety of academic problems (Isquith, Crawford, Espy, & Gioia, 2005; Miller & Hinshaw, 2010). Thus, there has been significant interest in the development of various instruments to measure attention in children such as parent rating questionnaires, continuous performance tests, and visual discrimination tests so that early and effective interventions can be provided.

The d2 test of attention is a paper-and-pencil measure of selective attention, concentration, and speeded visual perceptual discrimination that has been widely used in pediatric populations (Brickenkamp, 1994). The individual is asked to identify relevant targets (the letter d with two apostrophe marks that may be located above, both below, or one above and one below the d), while ignoring/suppressing irrelevant distracters, including orthographically similar stimuli (the letter d with one, three or four marks as well as the letter p with one or two marks). The stimuli are organized in 14 rows of 47 letters each (658 total elements, 229 relevant targets). Task instructions require the individual to scan each row from left to right for 20 seconds crossing out as many relevant elements as possible before the examiner prompts him or her to move to the subsequent row. Total test duration is between 8 and 10 minutes (Brickenkamp, 1981).

Percent rank scores based on age-based norms are calculated from the individual’s task performance. The following scales include: 1) speed which derives from the total number of correctly identified relevant responses, 2) accuracy which is based on the number of omission and commission errors, 3) total which measures the number of correct responses subtracting errors, and 4) variability or fluctuation rate which is based on the difference in correct responses between the rows with the highest and lowest number of correct responses (Brickenkamp, 1981).

The d2 test has also shown to have strong psychometric properties with high values of internal consistency, ranging between 0.95 and 0.98, and a validity coefficient of 0.47 (Bates & Lemay, 2004; Brickenkamp, Schmidt-Atzert, Liepmann, & Zillmer, 2013). The Spanish adaptation of the d2 test has similarly shown high reliability coefficient values of around 0.90 (Izquierdo et al., 2007). A convergent validity study with children aged 8–12 years old revealed high correlation between the overall d2 measure with other instruments for assessing attention in children such as the Faces Differences Perception Test (DPT) and Trees Simple Visual Discrimination Test (DiViSA-UAM). Notably, the omission errors index of the d2 test did not correlate significantly with any of the DPT or DIVISA measures (Lozano, Capote, & Fernandez, 2015). These findings may reflect the greater visual discrimination demands of the d2 in which individuals may be vulnerable to omission errors due to perceptual discrimination difficulties rather than attention lapses alone. Commission errors of the d2 showed significant correlations with the Faces-DPT ($r = 0.236$).

Demographic variables that may influence performance on the d2 test have been explored in pediatric populations, along with normative studies. Prior studies with the d2 and other measures of attention have not indicated significant differences according to sex, whether in attention or impulsivity (Klenberg, Korkman, & Lahti-Nuutila, 2001; Lin, Hsiao, & Chen, 1999; Quiroga, Santacreu, Montoro, Martínez-Molina, & Shih, 2011; Santacreu, Shih, & Quiroga, 2010). Normative data has been published for 1032 children from the Spanish Canary Islands who are 6–12 years old (Jiménez et al., 2012), showing significant developmental changes over time. A linear progression was observed, particularly in the areas of productivity and effectiveness but not in error measurement. In another study comparing the d2 to other attention measures such as the DiVisa-UAM and Faces Differences Perception Test, the d2 indicated a significant increase up to the 5th grade whereas the other two measures showed a progressive and significant increase in attention performance for children across school grades (Lozano et al., 2015). In contrast, the omission errors index of the d2 did not show a significant progression. Significant age differences were also not found for commission errors or impulsivity on the d2 test (Lozano et al., 2015). Culbertson and Sari (1997) conducted a pilot normative project of the d2 test with 54 American children, showing significantly greater productivity, accuracy, and variability performance with older age. Overall, results with the d2 test is consistent with evidence showing a significant progression in selective and sustained attention between eight and 12 years old, as well as stability of performance.

The d2 test has been used in various international pediatric clinical populations. Cserjési, Molnár, Luminet, and Lénárd (2007) found that Hungarian boys with obesity performed worse on the d2 test of attention when compared with their normal-weight same-aged peers, bolstering the evidence for childhood obesity leading to adverse effects on the development of attention. Recent evidence also suggests that children with low functioning autism spectrum disorders demonstrate reduced d2 performance in comparison to high functioning autism children, and that the degree of deficits was associated with abnormal neural connectivity (Han & Chan, 2017). A recent Brazilian study showed that children with prenatal alcohol exposure performed worse on the d2 test compared to same-aged peers in terms of speed, total errors, and omission errors (Furtado & Roriz, 2016). Begega and colleagues (2010) demonstrated no significant differences in d2 performance between preterm and full-term 8- and 9-year old children. The d2 has also been sensitive to attention difficulties often seen in epilepsy; clinical characteristics such as epilepsy duration and antiepileptic (AED) polytherapy have been associated with significantly worse d2 performance (Rahmann, Stodieck, Husstedt, & Evers, 2002).

More recently, the d2 test has also been utilized to measure the effectiveness of treatment programs in children. Fuchs, Birbaumer, Lutzenberger, Gruzelier, and Kaiser (2003) recently demonstrated that a 3-month neurofeedback program contingent on the suppression of theta/high beta and on the enhancement of SMR/low beta activity in EEG and pharmacotherapy was associated with improvements on the speed and accuracy measures of the d2. That is, children were able to work on more items while making fewer mistakes after treatment. Similarly, Mohammadi, Malmir, Khaleghi, and Aminiorani (2015) showed that neurofeedback along with methylphenidate led to improvements in d2 test performance. In the area of obesity and wellness, brief classroom-based exercise at low to moderate intensity had no acute effects on information processing speed and selective attention as measured by the d2 compared to a sedentary control condition in Dutch adolescents (van den Berg et al., 2016). However, Gallotta and colleagues (2015) demonstrated that obese and overweight children who participate in coordinative exercise at school exhibit significant improvements in attention/concentration and percentage of errors without improvements in total number of items processed on the d2 test. Even acute coordinative exercise has led to improvements in attention as measured by the d2 test (Budde, Voelcker-Rehage, Pietraßyk-Kendziorra, Ribeiro, & Tidow, 2008).

Previous normative studies of the d2 have been small or geographically limited; therefore, the lack of normative data could translate to erroneous clinical interpretation when evaluating Spanish-speaking or Hispanic/Latino children. Although there has been a Spanish adaptation of the d2 and it showed high internal consistency, norms for the d2 have not been established for children living in Latin America. Moreover, there is a dearth of adapted and well-normed tests available for use with Spanish speakers. In light of its brief duration and adequate psychometric properties, the main purpose of this study is to provide normative data for healthy children across nine Latin American countries and Spain in order to support its clinical utility.

2. Method

2.1. Participants

The sample consisted of 4,373 healthy children who were recruited from Chile, Cuba, Ecuador, Guatemala, Honduras, Mexico, Paraguay, Peru, Puerto Rico, and Spain. Participants were selected based on the following criteria: a) age between 6 and 17 years old, b) were born and currently lived in a country where the study was conducted, c) spoke Spanish as their mother tongue, d) an IQ $\geq$80 on the Test Of Non-verbal Intelligence (TONI-2, Brown, Sherbenou, & Johnsen, 2009), and e) a score <19 on the Children's Depression Inventory (CDI, Kovacs, 1992).

Children with history of neurologic or psychiatric disorders, as reported by the participant's parent(s), were excluded due to their effects on cognitive performance. Participants in the study were from public or private schools, and they signed an informed consent to participate. Socio-demographic and participant characteristics for each of the countries' samples have been reported elsewhere (Rivera & Arango-Lasprilla, 2017). Ethics Committee approval was obtained for the study in each country.

2.2. Instrument administration

d2 test is a measure of selective attention and mental concentration, as well as impulsivity (Wassenberg et al., 2008). It consists of 14 rows of 47 characters each, which can be the letters "d" or "p" with one, two, three, or four apostrophe marks located at the top and/or bottom of each letter. The examinee is asked to cross out the greater amount of "d" that have two apostrophe marks both above, both underneath, or one above and another below with 20 seconds allotted per row (Brickenkamp, 2012). The scores that are obtained in this test are Total number of items processed (TN), Total number of correct responses (CR), Omission errors (OE), Commission errors (CE), Total performance (TP), Concentration performance (CP) and Fluctuation rate (FR), and whose combination reflect three components of attentional behavior: the speed or quantity of work, the quality of the work (degree of precision) and the relationship between both (Wassenberg et al., 2008). In the present study, normative data for TN, CR, TP and CP will be provided.

2.3. Statistical analyses

Detailed statistical analyses used to generate the normative data for the d2 test scores are described in Rivera & Arango-Lasprilla (2017). The scores were standardized using multiple linear regression analyses by means of a four-step procedure. 1) First, the TN, CR, TP, and CP scores were computed separately by means of the final multiple regression models. The full regression models included as predictors: age, age^2, sex, and mean level of parental education (MLPE). Age was centered (= calendar age – mean age in the sample by country) before computing the quadratic age term to avoid multicollinearity (Aiken & West, 1991). Sex was coded as male = 1 and female = 0. The MLPE variable was coded as 1 if the participant's parent(s) had > 12 years of education or 0 if participant's parent(s) had $\leq$12 years of education. If predicted variables were not statistically significant in the multivariate model with an alpha of 0.05, the non-significant variables were removed and the model was run again. A final regression model was conducted $\hat{\mathrm{y}}_{\mathrm{i}} = \mathrm{B}_0 + \mathrm{B}_1 \cdot \left(Age - \bar{x}_{Age\ by\ country}\right)_i + \mathrm{B}_2 \cdot \left(Age - \bar{x}_{Age\ by\ country}\right)_i^2 + \mathrm{B}_3 \cdot Sex_i + \mathrm{B}_4 \cdot MLPE_i$ 2) Residual scores were calculated based on the final model ($e_i = \mathrm{y}_{\mathrm{i}} - \hat{\mathrm{y}}_{\mathrm{i}}$). 3) Residuals were standardized using the residual Standard Deviation (SD_e) value provided by the regression model: $\mathrm{z}_{\mathrm{i}} = \mathrm{e}_{\mathrm{i}}/SD_e$. 4) Standardized residuals were converted to percentile values using the standard normal cumulative distribution function. This four-step process was applied to TN, CR, TP, and CP scores separately for each country.

For all multiple linear regression models, the following assumptions were evaluated: a) multicollinearity by the values of the Variance Inflation Factor (VIF), which must not exceed 10, and the collinearity tolerance values, which must not exceed the value of 1 (Kutner, Nachtsheim, Neter, & Li, 2005), and b) the existence of influential values by calculating the Cook's distance. The maximum Cook's distance value was related to a $F\,(p, n-p)$ distribution. Influential values are considered when percentile value is equal or higher than 50 (Cook, 1977; Kutner et al., 2005). All analyses were performed using SPSS version 23 (IBM Corp., Armonk, NY).

3. Results

3.1. d2 - Total number of items processed (TN)

The final multivariate linear regression models for the ten country-specific d2 TN scores were significant (see Table 1). In all countries, the d2 TN scores increased linearly as a function of age. The d2 TN score for Guatemala and Puerto Rico were affected by a quadratic age effect. Children from Mexico, Puerto Rico, and Spain whose parents had a MLPE >12 years obtained higher d2 TN scores than children whose parents had a MLPE ≤12 years. The child's sex did not affect the d2 TN scores for any country. The amount of variance these predictors explained in the d2 TN scores ranged from 35.7% (in Puerto Rico) to 61.2% (in Mexico).

Table 1
Final multiple linear regression models for d2 TN

	B	Std. Error	*t*	Sig.	R^2	*SDe* (residual)
Chile						
Constant	360.391	3.975	90.664	<0.001	0.502	77.691
Age	22.473	1.148	19.584	<0.001		
Cuba						
Constant	393.880	4.659	84.551	<0.001	0.574	90.691
Age	30.490	1.352	22.550	<0.001		
Ecuador						
Constant	369.525	4.609	80.179	<0.001	0.418	79.291
Age	19.451	1.336	14.558	<0.001		
Guatemala						
Constant	344.476	6.208	55.487	<0.001	0.434	68.181
Age	22.016	2.033	10.830	<0.001		
Age^2	1.175	0.588	1.998	0.047		
Honduras						
Constant	311.853	3.710	84.048	<0.001	0.585	62.962
Age	23.171	1.152	20.115	<0.001		
Mexico						
Constant	333.720	3.522	94.758	<0.001	0.612	68.020
Age	24.465	0.698	35.075	<0.001		
MLPE	10.030	4.873	2.058	0.040		
Paraguay						
Constant	374.899	4.224	88.760	<0.001	0.501	73.029
Age	20.941	1.211	17.297	<0.001		
Peru						
Constant	399.627	5.273	75.791	<0.001	0.538	84.686
Age	26.932	1.541	17.472	<0.001		
Puerto Rico						
Constant	367.594	14.514	25.327	<0.001	0.357	88.271
Age	15.375	1.970	7.804	<0.001		
Age^2	–1.618	0.628	–2.576	0.011		
MLPE	38.605	14.501	2.662	0.008		
Spain						
Constant	337.567	3.708	91.029	<0.001	0.608	67.847
Age	25.218	0.665	37.919	<0.001		
MLPE	13.784	4.646	2.967	0.003		

Note. MLPE: Mean level of parental education.

3.2. d2 - Total number of correct responses (CR)

The final multivariate linear regression models for the ten country-specific d2 CR scores were significant (see Table 2). In all countries, the d2 CR scores increased linearly as a function of age. The d2 CR scores for Mexico were affected by a quadratic age effect. Children from Mexico, Puerto Rico, and Spain whose parents had a MLPE >12 years obtained higher d2 CR score than children whose parents had a MLPE ≤12 years. The child's sex did not affect the d2 CR scores for any country. The amount of variance these predictors explained in the d2 CR scores ranged from 32.3% (in Puerto Rico) to 58.5% (in Cuba).

Table 2
Final multiple linear regression models for d2 CR

	B	Std. Error	*t*	Sig.	R^2	*SDe* (residual)
Chile						
Constant	134.595	1.514	88.871	<0.001	0.524	29.600
Age	8.950	0.437	20.470	<0.001		
Cuba						
Constant	142.165	2.100	67.689	<0.001	0.585	40.888
Age	14.060	0.610	23.066	<0.001		
Ecuador						
Constant	131.740	1.923	68.505	<0.001	0.436	33.085
Age	8.415	0.557	15.094	<0.001		
Guatemala						
Constant	130.423	2.068	63.070	<0.001	0.356	28.653
Age	8.387	0.816	10.278	<0.001		
Honduras						
Constant	111.459	1.567	71.149	<0.001	0.510	26.583
Age	8.409	0.486	17.291	<0.001		
Mexico						
Constant	121.302	2.072	58.549	<0.001	0.541	30.281
Age	9.308	0.311	29.955	<0.001		
Age^2	–0.244	0.102	–2.384	0.017		
MLPE	10.286	2.180	4.719	<0.001		
Paraguay						
Constant	133.225	1.824	73.037	<0.001	0.460	31.538
Age	8.327	0.523	15.925	<0.001		
Peru						
Constant	143.517	2.229	64.398	<0.001	0.546	35.794
Age	11.572	0.652	17.762	<0.001		
Puerto Rico						
Constant	130.391	5.233	24.916	<0.001	0.323	37.521
Age	7.141	0.764	9.347	<0.001		
MLPE	13.120	6.145	2.135	0.034		
Spain						
Constant	130.803	1.628	80.354	<0.001	0.566	29.783
Age	10.124	0.292	34.680	<0.001		
MLPE	8.069	2.040	3.956	<0.001		

Note. MLPE: Mean level of parental education.

3.3. d2 - Total performance (TP)

The final multivariate linear regression models for the ten country-specific d2 TP scores were significant

Table 3
Final multiple linear regression models for d2 TP

	B	Std. Error	*t*	Sig.	R^2	*SDe* (residual)
Chile						
Constant	343.290	5.216	65.811	<0.001	0.588	67.301
Age	23.110	0.995	23.217	<0.001		
Age^2	–0.656	0.326	–2.012	0.045		
Cuba						
Constant	357.503	4.394	81.367	<0.001	0.625	85.535
Age	31.998	1.275	25.092	<0.001		
Ecuador						
Constant	332.614	4.046	82.211	<0.001	0.511	69.606
Age	20.587	1.173	17.553	<0.001		
Guatemala						
Constant	324.025	4.870	66.540	<0.001	0.432	67.473
Age	23.143	1.922	12.043	<0.001		
Honduras						
Constant	284.381	3.351	84.857	<0.001	0.620	56.867
Age	22.510	1.040	21.635	<0.001		
Mexico						
Constant	307.030	4.476	68.588	<0.001	0.628	65.426
Age	24.186	0.671	36.025	<0.001		
Age^2	–0.535	0.221	–2.415	0.016		
MLPE	20.034	4.710	4.254	<0.001		
Paraguay						
Constant	344.572	5.924	58.167	<0.001	0.556	65.962
Age	21.022	1.096	19.188	<0.001		
Peru						
Constant	364.170	4.742	76.798	<0.001	0.595	76.160
Age	27.192	1.386	19.615	<0.001		
Puerto Rico						
Constant	342.750	13.738	24.949	<0.001	0.394	83.552
Age	16.168	1.865	8.669	<0.001		
Age^2	–1.494	0.594	–2.514	0.013		
MLPE	34.400	13.726	2.506	0.013		
Spain						
Constant	326.062	4.429	73.626	<0.001	0.609	67.686
Age	25.231	0.666	37.899	<0.001		
Age^2	–0.431	0.214	–2.018	0.044		
MLPE	17.202	4.638	3.709	<0.001		

Note. MLPE: Mean level of parental education.

Table 4
Final multiple linear regression models for d2 CP

	B	Std. Error	*t*	Sig.	R^2	*SDe* (residual)
Chile						
Constant	128.735	1.608	80.064	<0.001	0.555	31.426
Age	10.112	0.464	21.785	<0.001		
Cuba						
Constant	132.611	2.265	58.554	<0.001	0.587	44.090
Age	15.243	0.657	23.189	<0.001		
Ecuador						
Constant	118.239	2.682	44.092	<0.001	0.471	35.035
Age	9.519	0.596	15.966	<0.001		
Sex	10.081	4.186	2.408	0.017		
Guatemala						
Constant	118.506	2.670	44.388	<0.001	0.390	31.794
Age	9.578	0.918	10.437	<0.001		
MLPE	10.584	5.343	1.981	0.049		
Honduras						
Constant	101.910	2.300	44.301	<0.001	0.516	28.421
Age	9.104	0.523	17.400	<0.001		
Sex	7.703	3.379	2.280	0.023		
Mexico						
Constant	111.382	2.348	47.436	<0.001	0.518	34.318
Age	9.981	0.352	28.344	<0.001		
Age^2	–0.288	0.116	–2.479	0.013		
MLPE	14.601	2.470	5.911	<0.001		
Paraguay						
Constant	114.647	3.101	36.970	<0.001	0.493	31.515
Age	8.791	0.529	16.625	<0.001		
MLPE	8.357	3.858	2.166	0.032		
Peru						
Constant	134.761	2.425	55.577	<0.001	0.515	38.944
Age	11.824	0.709	16.681	<0.001		
Puerto Rico						
Constant	131.541	2.918	45.075	<0.001	0.285	41.669
Age	7.403	0.822	9.004	<0.001		
Spain						
Constant	129.501	2.055	63.026	<0.001	0.557	31.404
Age	10.512	0.309	34.031	<0.001		
Age^2	–0.245	0.099	–2.471	0.014		
MLPE	9.401	2.152	4.369	<0.001		

Note. MLPE: Mean level of parental education.

(see Table 3). In all countries, the d2 TP scores increased linearly as a function of age. The d2 TP scores for Chile, Mexico, Puerto Rico, and Spain was affected by a quadratic age effect. Children from Mexico, Puerto Rico, and Spain whose parents had a MLPE >12 years obtained higher d2 TP scores than children whose parents had a MLPE ≤12 years. The child's sex did not affect the d2 TP scores for any country. The amount of variance these predictors explained in the d2 TP scores ranged from 39.4% (in Puerto Rico) to 62.8% (in Mexico).

3.4. d2 - Concentration performance (CP)

The final multivariate linear regression models for the ten country-specific d2 CP scores were significant (see Table 4). In all countries, the d2 CP score increased linearly as a function of age. The d2 CP scores for Mexico and Spain were affected by a quadratic age effect. Children from Guatemala, Mexico, Paraguay, and Spain whose parents had a MLPE >12 years obtained higher d2 CP scores than children whose parents had a MLPE ≤12 years. The child's sex affected d2 CP scores for Ecuador and Honduras, favoring boys. The amount of variance these predictors explained in the d2 CP score ranged from 28.5% (in Puerto Rico) to 58.7% (in Cuba).

The assumptions of multiple linear regression analysis were met for all final models. There was not multicollinearity (the VIF values were below 10; VIF ≤1.199; collinearity tolerance values did not exceed the value of 1) or influential cases (the maximum Cook's distance value was 0.098 in a $F_{(2,298)}$ distribution which corresponds to the 9th percentile).

3.5. Normative procedure

Norms (e.g., a percentile score) for the different d2 test scores by country were established using the four-step procedure described in the statistical analysis section. An example will be provided to facilitate an improved understanding of the procedure used to obtain the percentile associated with a score on this test. Let us assume that we need to find the percentile score for a 17-year-old Puerto Rican girl who scored a 500 on the d2 TP and whose parent(s) have a mean of 6 years of education (MLPE). There are several steps to obtain the percentile for this score: First, find Puerto Rico in Table 3, which provides the final regression models by country for the d2 TP scores. Use the B weights to create an equation that will allow you to obtain the predicted d2 TP score for this child using the coding provided in the statistical analysis section. The corresponding B weights are multiplied by the centered age (= calendar age – mean age in the Puerto Rican sample which is equal to 12.2 years), centered age^2 (= calendar age – mean age in the Puerto Rican sample which is equal to 12.2 years)^2, and MLPE was coded based on the 12 years of education threshold. Gender was not a significant predictor, therefore, it is not included in the model. See Rivera and Arango-Lasprilla (2017) to figure out the mean age of each country's sample. The result is subsequently added to the constant generated by the model in order to calculate the predicted value.

In the case of the Puerto Rican girl, the predicted d2 TP score would be calculated using the following equation: $\hat{y}_i = 342.750 + [16.168 \cdot (Age_i - 12.2)] + [-1.494 \cdot (Age_i - 12.2)_i^2] + (34.400 \cdot MLPE_i)$. The girl's age is 17 years old. The MLPE (6 years) is split into either $\leq$12 years (and assigned a 0) or more than 12 years (and assigned a 1) in the model. Since the parent(s) of the hypothetical child in the example have 6 years of education, the MLPE value is 0. As previously mentioned, sex was not significant predictor of d2 TP score, therefore, it should not be used in the formula. The predicted value equation is: $\hat{y}_i = 342.750 + [16.168 \cdot (17 - 12.2)] + \left[-1.494 \cdot (17 - 12.2)^2\right] + (34.400 \cdot 0) = 385.934$. In order to calculate the residual value (indicated with an e_i in the equation), subtract the actual d2 TP score (she scored 500) from the predicted value just calculated ($e_i = y_i - \hat{y}_i$). In this case, it would be $e_i = 500 - 385.934 = 114.066$. Next, consult the SD_e column in Table 3 to obtain the country-specific SD_e (residual) value. For Puerto Rico, it is 83.552. Using this value, we can transform the residual value to a standardized z score using the equation $z_i = e_i/SD_e$. In this case, we have $114.066/83.552 = 1.365$. This is the standardized z score for a 17-year-old Puerto Rican girl who scored a 500 on the d2 TP who has parents with 6 years of education (MLPE). The last step is to use the tables available in most statistical reference books (e.g., Strauss, Sherman, & Spreen, 2006). In this example, the z score of 1.365 corresponds to the 91st percentile. It is important to remember to use the appropriate tables that correspond to each test (TN, CR, TP, and CP) when performing these calculations.

3.6. User-friendly normative data

The four-step normative procedures explained above offers the clinician the ability to determine an exact percentile for a child who has a specific score on the d2 test. However, this method can be prone to human error due to the number of required computations by hand. To enhance user-friendliness, the authors have completed these steps for a range of raw scores based on age, sex, and MLPE and created tables for clinicians to more easily obtain a percentile range/estimate associated with a given raw score on this test. These tables are available by country and type of test in the Appendix. In order to obtain an approximate percentile for the above example (converting a raw score of 500 on the d2 TP test for a Puerto Rican girl who is 17 years old and whose parent(s) have 6 years of education) using the simplified normative tables provided in the Appendix, the following steps must be followed: (1) First, identify the appropriate table ensuring the appropriate country and test (TN, CR, TP, and CP). In this case, the table for d2 TP score for Puerto Rico can be found in Table A29. (2) Next, the table is divided based on MLPE ($\leq$12 vs. more than 12 years of education). Since the parent(s) had 6 years of education, we will use the bottom section of the table for $\leq$12 years of MLPE. (3) Find the appropriate age of the child, in this case, 17 years old. (4) Next, look in the 17 years' age column to find the approximate location of the raw score obtained on the test. Within the 17 years' column, the score of 500 obtained by this Puerto Rican girl corresponds to the 90th percentile.

The percentile obtained using this user-friendly table is slightly different than the hand-calculated, more accurate method (91st vs. 90th) because the user-friendly table is based on a limited number of percentile values. Individual percentiles cannot be presented in these tables due to space limitations. If the exact score is not listed in the column, you must estimate the percentile value from the list of raw scores available.

4. Discussion

The purpose of this study was to obtain normative data for the d2 test for children and adolescents from nine Latin American countries (Chile, Cuba, Ecuador, Guatemala, Honduras, Mexico, Paraguay, Peru, and Puerto Rico) and Spain. The final regression models for the d2 test explained between 35.7% and 61.2% of the variance for the TN; between 32.3% and 58.5% of the variance for the CR; between 39.4% and 62.8% of the variance for the TP; and between 28.5% and 58.7% of the variance for the CP.

Age was significantly related to all d2 scores in all countries. That is, scores increased linearly as children became older. Similarly, Jiménez et al. (2012) found a linear effect of age in the measures of productivity and effectiveness obtained from the TN, CR, TP, and CP scores, and not in the error measures for a pediatric Spanish population. Culbertson and Sari (1997) obtained similar findings, showing that variability (FR) was also influenced by age. Studies have consistently shown an increase in attention capacity as children become older with neuropsychological tests other than the d2 (Korkman, Kemp, & Kirk, 2001; Rosselli, Ardila, Bateman, & Guzmán, 2001; Rosselli et al., 2004; Matute, Sanz, Gum, Rosselli, & Ardila, 2009). The explanation for these results can be found in the progressive development of the mechanisms involved in the inhibition of irrelevant information (Dempster, 1992; Gómez-Pérez, Ostrosky-Solís, & Próspero-García, 2003) as well as cortical maturation.

In the case of the quadratic function of age, the effect found was much lower than the linear function of age. That is, the results were only significant for the d2 TN in Guatemala and Puerto Rico. Results for the d2 CR were only significant for Mexico, and results for the d2 TP were significant for Chile, Mexico, Puerto Rico, and Spain. Finally, results for the d2 CP were only significant for Mexico and Spain. These results confirm that attentional processes usually develop in a linear fashion as children grow, or at least until the age of 17 years.

In the present study, sex was only significantly related to the CP scores in Ecuador and Honduras. However, in previous studies (Klengberg et al., 2001; Lin et al., 1999; Quiroga et al., 2011; Santacreu et al., 2010) sex was not related to d2 test scores. This shows that unlike other psychological processes such as language (Fenson et al., 1994; Huttenlocher, Haight, Bryk, Seltzer, & Lyons, 1991; Morisset, Barnard, & Booth, 1995) whose development occurs earlier in girls than in boys, attention seems to develop in a more stable manner over time in healthy children, regardless of sex.

Parental education has been shown to be a critical variable when investigating cognitive performance in children (Meador et al., 2011; Schady, 2011), especially language functions (Hoff & Tian, 2005; Hoff, Laursen, & Tardif, 2002). However, little consideration has been paid to the relationship between parental education and attention. Indeed, our study indicates that parental education significantly contributes to attentional skills. More specifically, the parent's educational level was found to be significant for the four d2 scores in Mexico, Spain, and Puerto Rico (except for d2 CP), whereas in Guatemala and Paraguay for the CP, favoring children with higher parental education. Similar to our findings, Matute et al. (2009) demonstrated that lower parental education level was associated with reduced attention and memory performance in children, particularly in older children.

4.1. Limitations and future directions

This study is the largest in the world that has been developed for the validation and standardization of the d2 test of attention in Spanish-speaking children. Nevertheless, it is important to mention some limitations related to the generalization and interpretation of our findings: This study presents normative data for the d2 test for nine countries from Latin America and Spain. For this reason, it is not advisable to use these norms in the pediatric population of those Spanish-speaking countries where the study was not performed. Future studies should be conducted to standardize this test in other Spanish-speaking countries.

Although the norms of the present study could be used by neuropsychologists in other countries to evaluate Spanish-speaking immigrant children from the countries where the sample was collected for this study, they should be used with caution since other variables such as level of acculturation, bilingualism, the number of years living in the country, and so on, could influence performance. In addition, the quality of education of both the child and the parents is another aspect that may influence the cognitive performance of children.

Although the d2 test is one of the most used instruments to evaluate attention, it is very important to keep in mind that no clinical diagnosis should be made based solely on the scores of this test alone. In combination with a clinical history, behavioral observations and objective questionnaires that measure attention skills in multiple settings, this test should be integrated as part of a comprehensive battery that evaluates these processes in detail. Because there are a limited number of tests and norms in Latin America and Spain to evaluate these processes, more efforts should be made in the future to develop other similar tools.

The size of the sample was adequate in each of the countries where the study was conducted. However, only the sample in Chile, Mexico, Paraguay, Puerto Rico, and Spain was obtained from several regions of the country whereas the samples from the remaining countries represented only one geographic area. Future studies should expand the sample in other geographical areas of these countries to increase the representativeness of the sample.

Finally, it is important to keep in mind that the present study was performed with a healthy and typically developing pediatric population. Therefore, future studies should be performed with clinical populations to establish the sensitivity and specificity of the d2 test in Spanish-speaking children.

4.2. Implications and conclusions

This is the first and most extensive multicenter study carried out so far with the d2 test, offering normative data for children from nine Latin America countries and Spain. The current approach used for the creation and development of normative data in this study (the use of multiple regressions and residual values) is more precise than the use of average scores and standard deviations.

The addition of parental education and the quadratic function of age in the final regression models are some of the main advantages this study has in comparison to previous normative studies of the d2 test that have not taken these variables into account (e.g. Culbertson & Sari, 1997; Jiménez et al., 2012). Notably, the socio-demographic variables included in the model explain a high proportion of the variance of the d2 test scores (between 28.5% and 62.8%). In light of the high prevalence of attention problems in children and ADHD being the most common reason for referral for pediatric neuropsychological evaluation in Latin America, it is necessary to have adequate assessment tools to detect these problems and advance clinical decision making for diagnostic purposes. Therefore, the results of this study are expected to contribute to clinical practice across Latin America and Spain by improving the quality of how attention is assessed during routine pediatric neuropsychological evaluations.

Conflict of interest

None to report.

Supplementary material

The Appendix tables are available in the electronic version of this article: http://dx.doi.org/10.3233/NRE-172248.

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