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NORMATIVE DATA FOR FOUR NEUROPSYCHOLOGICAL TESTS IN A SAMPLE OF ADULTS WHO ARE ILLITERATE AND FROM LATIN AMERICA

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NORMATIVE DATA FOR FOUR NEUROPSYCHOLOGICAL TESTS IN A SAMPLE OF ADULTS WHO ARE ILLITERATE AND FROM LATIN AMERICA

A dissertation submitted in partial fulfillment of the requirements for the Doctor of Philosophy at Virginia Commonwealth University

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Table of Contents

Page

List of Tables …………………………………………………………………………… iv

List of Figures …...…………………………………………………………………... vi

Abstract …...…………………………………………………...…………………….. vii

Introduction
Overview……………………………………………………………..……. …10
Literature Review………………………………………………………...… 12
Statistics on Illiteracy ……………………………………..……………… 15
Statistics on Illiteracy: Latin America ……...………………………………….. 17
Statistics on Illiteracy: Sex Differences in Latin America.……………………... 19

Factors Associated with Illiteracy
Illiteracy and Poverty ………………………………………………………... 21
Illiteracy and Education ……………...………………………………………… 22
Illiteracy and Employment ……………………………………………………... 25
Illiteracy and Crime ………………………………………………………………. 26
Illiteracy and Health ………………...……………………………………….. 27

Illiteracy and Cognitive Process ..…………….……………………………………… .30
Lateralization of Brain Function…………………………..………………… 31
Neural and Anatomical Differences ……..…. ………………………………… 32
Cognitive Differences……………………………….. ……………………… 33
Learning and Visual Memory, and Visuospatial and Visual Motor Skills....…...34
Executive Functions…… …………………………..............………………. 36
Learning and Verbal Memory………......…………..…………..…………….. 37
Verbal Fluency ………………...…………………….. …………………………39
Summary ……………………………………………………………………...40

Importance of Normative Data ……………………………………………………….41
Normative Data with Populations Who are Illiterate ………………………..……..….44
Objective ……….. ………………………………………………………………….47

Method
Participants ……………………………………………………………………... 47
Sample Size and Power Analyses ………………...………………...………….. 49
Measures ……………………………………………………………………….. 51
Sociodemographic-Clinical Questionnaire………………………..………..…51
Screening Tests……………………..………………………………….…………..51
Neuropsychological Tests ………………………………...……………..54
Procedure
Training and Administration Procedure of the Battery……......……………..…. 64

Statistical Analysis
Independent Sample t-Tests……..…………………………………………….. 66
Psychometrics ……………………………………………………………..66
Normative Procedure …………………………………………………...….68
Results
Independent sample t-tests……..…………………………………………..… 70
Psychometrics………………………………………………………………………72
Assumptions …………………………………………………………………..75
Final Multiple Linear Regression Models..……………………………………………76
ROCF…………………………………………………………………..……. 76
Normative Data for the ROCF ………..………………………………...79
Use of Normative Data Tables for the ROCF …….……………………… 82
M-WCST ……………………………………………………………………...85
Normative Data for the M-WCST ………………………………..……..88
Use of Normative Data Tables for the M-WCST ………………….……89
Semantic Verbal Fluency……………………………………………………..….92
Normative Data for the Semantic Verbal Fluency Test …………..…….95
Use of Normative Data Tables for the verbal fluency tests……….….. ...96
HVLT-R ………………………………………………………………………..101
Normative Data for the HVLT-R …………………………………...….104
Use of Normative Data Tables for the HVLT-R……………………..…105
Discussion ……………………………………………………………………………...110
Implications……………………………………………………………………………..117
Limitations and Future Directions ……………………………..……………………118
References ……………………………………………………………………………...122

List of Tables

Page

Table 1a. Global Illiteracy Rates and Illiterate population of Adults and Youth, 2016 15

Table 1b. Percentages of Illiteracy in Latin America …..…………………………………… 18

Table 1c. Illiteracy Population Among Youth, Adults and Older Adults by Latin American Countries ……………………..……………………………………………………… 18

Table 1d. Latin America Illiteracy Rates Among Adults, Youth and Older Adults by Gender……………………………...………………………………………… 20

Table 1e. Percentage of Illiteracy by Gender in Latin America ………………..……………..20

Table 1f. Raking Scores for Reading and Mathematics, PISA 2015 …………………...…… 24

Table 1g. Summary of Published Normative Data with Illiterates…………………………... 46

Table 2a. Socio-Demographic Characteristics of the Sample ……………………..………49

Table 2b. Independent Sample t-Test and Effect Sizes by Type of Illiteracy…...……………71

Table 2c. Independent Sample t-Test and Effect Sizes by Country……………..………...72

Table 2d. Reliability Coefficients for Each Neuropsychological Test …….……….….……..73

Table 2e. Factor Loadings EFA and CFA ……………………………………….….……..74

Table 2f. Assumptions of Multicollinearity, Homoscedasticity, Normality and Influential Values for the Final Multiple Linear Regression Model.…………………….….…75

Table 3a Final Multiple Linear Regressions Models for the ROCF Scores……………...…..77

Table 3b Standard Deviation Residuals for the ROCF ……………………………………79

Table 3c. Corresponding Percentiles to the z_i values of the ROCF Memory…………………81

Table 3d. Normative Data for the ROCF Memory Stratified by Age ……………...……....83

Table 3e. Normative Data for the ROCF Copy Stratified by Age and Sex……………….…84

Table 4a. Final Multiple Linear Regression Models for the M-WCST Scores ……………. 85

Table 4b. Standard Deviation Residuals for the M-WCST …………………………………..86

Table 4c. Normative Data for the M-WCST Total Errors Stratified by Age…………………90

Table 4d. Normative data for the M-WCST Total Categories Stratified by Age …………… 91

Table 5a. Final Multiple Linear Regression Models for the Semantic Verbal Fluency Scores…………………………………………………………………………..92

Table 5b. Standard Deviation Residuals for the Semantic Verbal Fluency …………………...93

Table 5c. Normative Data Table for the Fruits Category Stratified by Age and Sex ……….. 98

Table 5d. Normative Data Table for the Animals Category Stratified by Age …….……….. 99

Table 5e. Normative Data Table for the Professions Category Stratified by Age …………...100

Table 6a. Final Multiple Linear Regression Models for the HVLT-R ………………………102

Table 6b. Standard Deviation Residuals for the HVLT-R …………………………………...104

Table 6c. Normative Data Table for the HVLT-R Total Recall Stratified by Age ……..…...107

Table 6d. Normative Data Table for the HVLT-R Delayed Recall Stratified by Age ………108

Table 6e. Normative Data Table for the HVLT-R Recognition Stratified by Age ………..... 109

Table 7a. Example of percentiles from example 1 of the Animals …..…………………...…115

Table 7b. Example of percentiles from example 2 of the M-WCST Total Categories………116

List of Figures

Page
Figure 1a. Illiteracy population among all adults (15+) by country …………..…………….. 18

Figure 2. Graph of estimated sample size using G*Power 3.1………………….………...50

Figure 3a. Predictive scores for the ROCF Copy …………………………….………..…77

Figure 3b. Predictive scores for the ROCF Memory ……………………………..………78

Figure 4a. Predictive scores for the M-WCST Correct categories ………….……………….86

Figure 4b. Predictive scores of the M-WCST Total errors ………………………………..87

Figure 5a. Predictive scores of the Animal category ………………………………………...93

Figure 5b. Predictive scores of the Fruits category………………………………………..94

Figure 5c. Predictive scores of the Professions category ……………………………………94

Figure 6a. Visual Representation of curvilinear effect for the HVLT-R Total Recall ……...102

Figure 6b. Predictive scores of HVLT-R Delay Recall ….. ………………………………..103

Figure 6c. Predictive scores of HVLT-R Recognition……………………………………103

Abstract

NORMATIVE DATA FOR FOUR NEUROPSYCHOLOGICAL TESTS IN A SAMPLE OF ADULTS WHO ARE ILLITERATE AND FROM LATIN AMERICA

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A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy at Virginia Commonwealth University

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Neuropsychological tests are standardized tasks used to measure psychological functioning that is associated with a particular brain structure. These tests often are used in diagnosing a cognitive deficiency resulting from brain injuries. Currently there are a limited number of studies that have focused on standardization of neuropsychological tests in Latin America. Therefore, the vast majority of cognitive tests used in the evaluation of patients with brain damage have no normative parameters adjusted to the cultural characteristics of Latinos and Latinas. As a result, neuropsychological diagnoses among this population may be inadequate, and evaluation of rehabilitation program effectiveness limited. The importance of culturally appropriate indices of neurological tests cannot be overstated; of all the problems

presented by individuals with brain injuries, cognitive disorders are the leading source of disability for adequate work, family and social reintegration among this group. There is an urgent need to standardize neuropsychological tests in Latin America, among Latinos in the US and any other regions where neuropsychological test have not been standardized. An important population subgroup in Latin America severely lacking in norms for many neuropsychological tests are those deemed illiterate or unable to read or write. In Latin America, this group comprises approximately 31 million people over the age of 15. The living conditions and lifestyles of this vulnerable population can lead to more accidents and personal injury resulting in brain damage. Thus, this group is likely to experience neuropsychological trauma and is in need of appropriate diagnosis and treatment. The present dissertation focused on the standardization and validation of four widely used neuropsychological tests: the Rey–Osterrieth Complex Figure, the Wisconsin Card Sorting Test-Modified, the Semantic Verbal Fluency, and the Hopkins Verbal Learning Test-Revised. The results show that there was no multicollinearity between the predictor variables in the final models according to the tolerance and VIF values. Second, the majority of tests indicated homoscedasticity, except for the ROCF Memory and the M-WCST Correct Categories, for these tests the residual standard deviation (SD_e) was estimated in each of the predictive scores quartiles in order to compensate for the lack of homoscedasticity in the model and to have greater precision in the generation of normative data. On the other hand the majority of the tests did not show a normal distribution (except for the M-WCST Total Errors, Animals, Fruits and the HVLT-R total recall), thus an empirical distribution function was used for the transformation of z_i to percentile. Finally, influential values were not found in the final models of all tests. The final multiple linear regression models for the ROCF showed an effect of age for both the memory and copy tasks, showing a linear decline, as participants get older.

However, the variables sex was only shown to be significant for the ROCF Copy, where older men had higher scores than older women. Regarding the M-WCST, the final multiple linear regression models revealed only an effect of age, for both Correct Categories and Total Errors, showing a linear decline of correct categories and an increase of errors, as subjects get older. It is important to note the final model for M-WCST Perseverations was not significant, thus normative data for this portion of the test was not developed. The Animals and Fruits categories of the semantic verbal fluency test had an effect of quadratic age, meaning a curvilinear increase in scores was observed up to approximately 50 years of age. A linear decline was only seen for the Professions category, where older people obtained lower scores than younger individuals. In addition, only the Fruits category showed an effect of sex, where women scored higher on this test than men. The final multiple linear regression models for the HVLT-R revealed a predictive effect of the variable age, for Total Recall, Delayed Recall and Recognition scores, showing a linear decline, as people get older. However, only the Total Recall scores showed a predictive effect for quadratic age, meaning a curvilinear increase in scores was observed up to approximately 50 years of age. Developing normative data for individuals who are illiterate will allow neuropsychologists to have a more accurate comparison when attempting to diagnose cognitive deficits among this group in Latin America. This dissertation is unique, as no other studies have looked at the normative data and standardization of neuropsychological tests within this population in Latin America.

Normative Data for Four Neuropsychological Tests in a sample of Adults who are Illiterate and from Latin America

Overview

Neuropsychology is subfield of psychology that studies the cognitive processes of both healthy populations and individuals with brain injuries and their relationship with behavior (Lezak, Howieson, & Loring, 2004). The use of neuropsychological tests during assessment is a very important part of a clinical neuropsychologist everyday work. Neuropsychological tests are essential to obtaining an objective measure of an individual's cognitive functioning in different areas, such as attention, executive functioning, memory, language, visuospatial skills, motor skills, and emotional and behavioral functioning (Baron, 2004; Lezak et al., 2004; Strauss, Sherman, & Spreen, 2006).

It is if vital importance to have normative data adjusted to the sociodemographic (e.g., age, education, literacy and sex) and cultural characteristics of individuals in order to effectively interpret a person's test score on a particular neuropsychological test (Lezak, et al., 2004; Strauss et al, 2006; Van der Elst, Molenberghs, Van Boxtel, & Jolles, 2013). If not, the probabilities of diagnostic bias could potentially increase (Daugherty, Puente, Fasfous, Hidalgo-Ruzzante, & Pérez-Garcia, 2017). Thus, not taking into consideration sociodemographic variables, clinicians can run the risk of assuming the existence of brain pathologies when assumed deficits are due to sociodemographic (e.g., education) differences relative to the population that was used to create normative data.

In Latin America some of the most commonly used neuropsychological tests unfortunately, despite their popular use, have not been validated in research and lack normative data (Arango-Lasprilla, Stevens, Morlett Paredes, Ardila, & Rivera, 2016). As a result, clinical neuropsychologists have been using normative data from other countries, personalized procedures through clinical practice, and/or raw scores without a comparison to normative data (Arango-Lasprilla et al., 2016). Thus, neuropsychological diagnoses among this population may be inadequate, and evaluation of rehabilitation program effectiveness limited. There is an urgent need to standardize neuropsychological tests in Latin America and among Latinos in the US.

Existing normative data methods have a number of limitations, such as the use of means and standard deviations within each subgroup (e.g., Malloy et al., 2007; Oliveira, Mograbi, Gabrig, & Charchat-Fichman, 2016), conversion of raw scores to metrics such as *Z* or *T* values (e.g., Schretlen, 2010; Golden, 2010; Rey, 2009), and having no representative samples (i.e., by culture or education) in their studies (e.g., Malloy et al., 2007; Matute, Rosselli, Ardila, & Morales, 2004). Each and one of these method limitations present a significant problem (Van Breukelen & Vlaeyen, 2005). In order to address a number of these limitations, the present dissertation used a method based on multiple linear regression and standard deviation of residual values (e.g., Van Breukelen & Vlaeyen, 2005), which will be addressed in the discussion section of this dissertation.

An important population subgroup in Latin America lacking normative data for many neuropsychological tests are those deemed illiterate. In Latin America, this group comprises approximately 31 million people over the age of 15. The living conditions and lifestyles (e.g., poverty, lack of education, unemployment/employment position, crime and/or health) of this vulnerable population can lead to more accidents and personal injury that could result in brain damage. Thus, this group is likely to experience neuropsychological trauma and is in need of appropriate diagnosis and treatment. Therefore, the objective of this dissertation was to develop normative data for four commonly used neuropsychological tests (ROCF, M-WCST, HVLT-R and the Semantic Verbal Fluency) in a group of individuals who are illiterate and from Latin

America. The method based on multiple linear regression and the standard deviations of residual values used in this dissertation allows for the identification of which variables predict test scores, identify and control for collinearity of predictive variables, and generate more reliable norms than those used with traditional methods. Having normative data for individuals who are illiterate will allow neuropsychologists to have a more accurate comparison when attempting to diagnose cognitive deficits among this group.

Literature Review

Illiteracy is a word of Latin origin (analphabetus) derived from the ancient Greek (ἀναλφάβητος, illiterate) that generally refers to a person who cannot read or write (Illiteracy, n.d). Illiteracy is recognized worldwide as one of the most serious problems that a country can experience (United Nations Educational, Scientific and Cultural Organization; UNESCO, 2016). Illiteracy has been compared to a disease that needs to be eradicated, and that its rates can give us an idea of the health of a country (UNESCO, 1964). The importance of literacy lies primarily in the power it gives to the literate; power to obtain information, communicate personally in writing and develop within social contexts that require the ability to read, write and understand as a requirement to actively participate in the processes and decisions of the same society (Cope & Kalantzis, 1993).

The term is also frequently used to label individuals who are ignorant or lack the most basic knowledge in any field (e.g., technology, music, science, ecology, health, environment; Mulcahy, 2012). The General Conference of the UNESCO, in 1978 stated that a person who is illiterate is one who cannot, with understanding, read and write a short simple statement in his/her everyday life (UNESCO, 1978, p.183). One of the purest forms of illiteracy would be not being able to read and write and never having attended school, which is refereed in the literature as *absolute illiteracy* (Reis & Castro-Caldas, 1997). This general understanding of the concept creates methodological challenges in terms of measurement. As such, experts abandoned the literate vs. illiterate dichotomy in favor of an approach which views literacy as an ongoing process, a continuum, including everything from the development of basic abilities to more complex linguistic and communication skills which unfold in a variety of social contexts, showing the obsolescence of such dichotomous thinking (UNESCO, 2010).

Initially, the Literacy Assessment and Monitoring Programme (LAMP), UNESCO and the Social Development Division of the Economic Commission for Latin America and the Caribbean (ECLAC) classified individuals with five years or less of formal education as illiterate (UNESCO, 2006). The International Council for Adult Education (ICAE) defines a person who is illiterate as someone aged 15 years or older who has not completed the second grade (ICAE, 2008). Furthermore, ECLAC has stated that a person who is illiterate is someone with 12 years or less of formal education (Torres, 2009). In fact, a pioneering study on literacy conducted by UNESCO-OREALC in the late 1990s in urban areas of seven Latin American countries (Argentina, Brazil, Colombia, Chile, Mexico, Paraguay and Venezuela) provided empirical evidence confirming that four years of education are not enough to ensure usable and sustainable reading and writing skills and that what matters is not only the number of years of education but also the quality of such education (Castro Ramirez, 1980; Infante, 2000).

To further expand the different definitions of illiteracy, the term *functional illiteracy* has also been introduced to include certain skills or functions of an individual not found in people who are absolute illiterates (One of the purest forms of illiteracy would be not being able to read and write and never having attended school; Jimenez Castillo, 2007; Reis et al., 1997). Even though the definition of functional illiteracy is somewhat vague, and crosses with some of the definitions of illiteracy previously given, people that are functionally illiterate are people who know how to read and write but do not meet a minimum standard of literacy (Functional illiterate, n.d.). Sometimes this group is also classified as *illiterate through disuse* because even after having acquired the basic skills in reading, writing and calculation, they forget it due to the lack of practice and opportunities (Barthe, 2016; Castro Ramirez, 1980; Infante, 1988; Morsy, 2013; Torres, 1995).

Functional illiteracy vs. absolute illiteracy may differ in the strict sense that absolute illiteracy implies the inability to read or write simple sentences in any language, while a functional illiterate, may function as a member of society to a certain extent with a varying degree of correctness and style. For example, an adult who is considered functionally illiterate may not be able to adequately solve necessary tasks in everyday life such as completing a job application, understanding a contract, following written instructions, reading an article in a newspaper, consulting a dictionary or understanding a brochure with bus schedules, but may be able to interpret traffic signs or recognize certain numbers when shopping (e.g., prices for objects or groceries commonly bought on a regular basis; Chamorro, 2017). Some individuals may even be able to write their names and have a basic mastery of reading, while their reading fluency and/or other skills related to literacy, such as reading speed, may be minimal or completely missing.

In conclusion, illiteracy refers to the lack of reading skills, different levels of reading and writing, and/or different levels of comprehension (Vágvölgyi, Coldea, Dresler, Schrader, & Nuerk, 2016). For this reason there are at least two types of people who are illiterates. The first includes individuals who never learned to read or write and have zero years of formal education, commonly known as *absolute illiterates*; and the second is *functional illiterates*, found among individuals who had never attended school but have some level of proficiency to cope with the demands of daily life.

Statistics on illiteracy

For more than 60 years the UNESCO has followed the progress of nations around the world in achieving higher rates of adult literacy, and although literacy has been a priority on the development agenda globally over the past decades, the latest data by the UNESCO Institute for Statistics (UIS) reports that 750 million adults are considered illiterate (i.e., individuals who cannot both read and write with understanding a short simple statement on their everyday life; UIS, 2016). In 2016, 102 million of the illiterate population was between 15 and 24 years of age (see Table 1a.).

Table 1a. Global illiteracy rates and illiterate population of adults and youth, 2016

Indicator	Adults (all) aged 15+	Youth aged 15-24 years	Adult aged 25-64	Older Adults aged 65+
Global illiterate population	750 million	102 million	506 million	140 million
Illiterate population men	277 million	44 million	186 million	46 million
Illiterate population, women	473 million	58 million	320 million	94 million
Illiteracy rate, men	37%	43%	37%	33%
Illiteracy rate, women	63%	57%	63%	67%

Even though adult illiteracy has been steadily declining for all countries, particularly over the past few decades, according to the latest literacy figures, the majority of countries missed the "Education for All" goal of reducing adult illiteracy rates by 50% between 2000 and 2015 (UNESCO, 2016). In 2016, Southern and Western Asia still remained the home to almost one-half of the global illiterate population (49% vs. 51% in 2005). Followed by 26% in sub-Saharan Africa (vs. 21% in 2005), 10% in Eastern Asia (vs. 14% in 2005), 9% in Arab States (vs. 8% in

2005) and 4.10% (vs. 5% in 2005) in Latin America (e.g., Mexico, South America and South America) (UNESCO, 2016; UIS, 2016).

At a global level, the adult and youth literacy rates are estimated to have grown by only 4% each over this period. In 2016, the youth illiteracy rates (ages 15 to 25) were lower than the adult (ages 25 to 64) and older adult (65+) population illiteracy rates, reflecting the increased access to education among younger generations (UIS, 2016). Yet, youth literacy rates remain low in several countries, most of them in sub-Saharan Africa (34% in 2016 vs. 28% in South and West Asia, 6% in Arab States, 3% East Asia and 1.28% in Latin America) suggesting problems with access to education, early school drop-out, poor quality of education and/or access to technology. In September 2015, with the implementation of the Sustainable Development Goals by the United Nations General Assembly, a number of countries pledged to attain a new target for the year 2030. Their goal is to ensure all youth and a significant proportion of adults, achieve literacy and numeracy (UNESCO, 2016).

Since the primary focus of this dissertation will be on Latin America, the following sections will present statistics and problems related to illiteracy for individuals from Latin America countries, not before introducing some of the similarities that all Latin American countries share. The term “Latino” has been used to identify a number of cultural or ethnic groups. According to the Merriam Webster dictionary, being Latino relates to being a native or inhabitant of Latin America (Latin America is composed of Mexico, Central America and South America) or a person of Latin American origin living in the U.S. (Latino, n.d.). Although Latinos are generally a heterogeneous group, many do share some common characteristics including language, socioeconomic status, religion, and educational attainment. First, the majority of Latinos speak Spanish as their primary language (77% of the population; Spanish SEO, 2008).

Second, even though income inequality has reduced in recent years, Latin America remains the most unequal region in the world, and as so, many report socioeconomic challenges; including a crippling 29.2% living in poverty in 2015 (vs. 28.2% in 2012; ECLAC, 2015). Third, the majority of Latinos identify themselves as Catholic (69%), followed by Protestant (19%) and unaffiliated (8%; Pew Research Center, 2014).

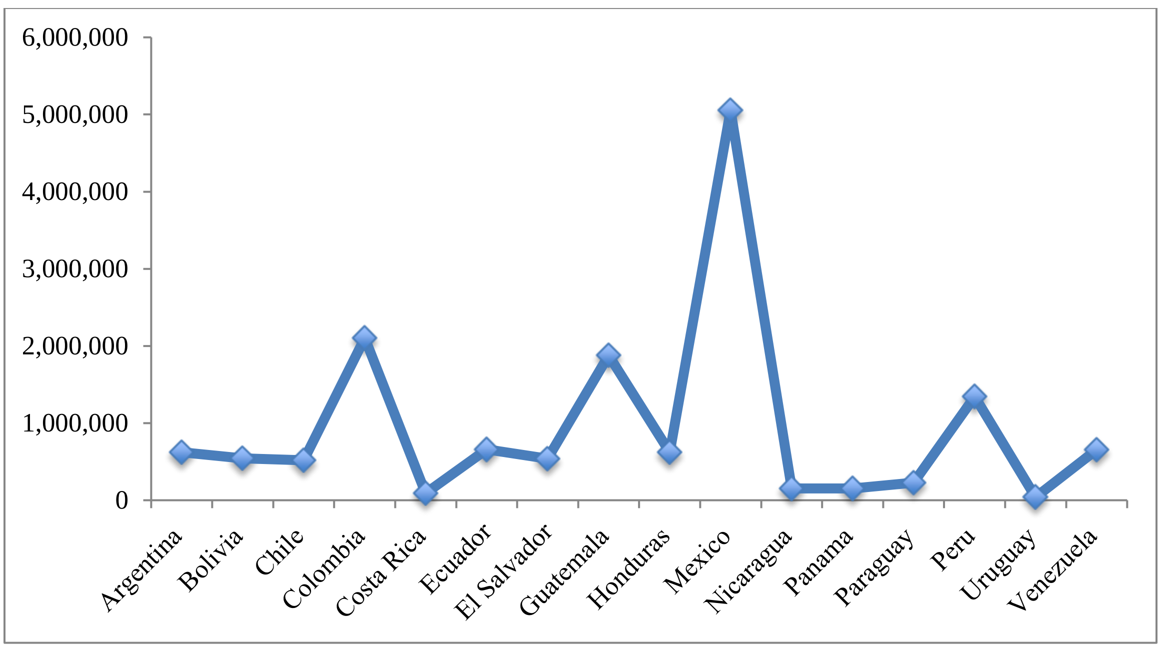
Statistics on illiteracy: Latin America

It is important to note that specific statistics for certain Latin American countries are not publically available, thus for the majority of this paper general information on Latin America will be presented and individual information will be provided when available. Illiteracy rates in Latin America dropped from 4.65% in 2005 to 4.13% in 2016 (UIS, 2016; see Figure 1a for illiteracy rates over the years). However, according to recent data, among older adult populations (those aged 65 years and older) illiteracy has steadily remained at 7% since 2006 (see table 1b), with even higher percentages of illiteracy found by country (UIS, 2016). The most pressing situation in found in the older adult population in Mexico with a steady percentage of 19% from 2005 to 2015. However, is also important to mention Mexico is the home to the most adult (14% from 2005 to 2015) and youth (13% from 2005 and 2015) who are illiterate out of all the countries surveyed by the UNESCO (UIS, 2016). Figure 1a shows a visual representation of the total adult population (15+) with a number of Latin American countries, clearly showing Mexico's outstanding illiteracy rates when compared to the rest of the countries. Even so, the steady level of illiteracy among the adult population forces the need to reinforce the specific policies of literacy and education for all those who for some reason were forced to interrupt their education trajectories (see Table 1c for illiteracy rate among youth, adults and older adults by country). In general, people that live in developing countries tend to be poor (Chen & Ravallion, 2008), have a shorter life span (Philipson & Soares, 2005), have higher rates of illiteracy (UNESCO, 2016), lack quality health care (Peters, Garg, Bloom, Walker, Brieger & Hafizur Rahman, 2008) and quality of education (Gordon, 2003; Winkler & Gerhberg, 2000). This persistence of illiteracy in developing countries is a representation of the many inequalities that continue to corrupt their societies.

Table 1b. Percentages of illiteracy in Latin America

Indicator	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Youth	2.40	2.37	2.24	2.04	2.14	1.79	1.66	1.68	1.41	1.35	1.28
Adults	4.65	4.42	4.36	4.29	4.39	4.00	4.06	4.08	3.87	3.79	3.69
Older Adults	6.58	6.94	6.93	7.11	7.48	7.36	7.25	7.35	7.30	7.34	7.27

Figure 1a. Illiteracy population among all adults (15+) by Latin American countries *



*Rates presented are from the latest information found for each country by UIS, 2016

Table 1c. Illiteracy population among youth, adults and older adults by Latin American countries

Country	Youth aged 15-24 years	Adults aged 24-64	Older Adults aged 65+

Argentina	48,105	340,191	232,904
Chile	26,452	272,477	203,579
Colombia	121,588	1,255,798	669,881
Costa Rica	7,166	51,445	669,881
Ecuador	27,856	341,525	254,802
El Salvador	25,389	332,773	176,851
Guatemala	186,110	1,281,939	382,452
Honduras	68,859	390,588	136,888
Mexico	245,994	2,781,622	1,886,258
Nicaragua	154,300	488,073	116,800
Panama	14,900	87,035	47,100
Paraguay	22,386	114,695	74,918
Peru	62,100	808,405	496,411
Uruguay	5,570	19,897	146,82
Venezuela	68,340	336,354	241,937

Source: UIS, 2016

Statistics on Illiteracy: Sex differences in Latin America

Globally illiteracy rates have been declining over time, but women still make up the majority of adults who are illiterate in every region, accounting for 473 million of the global adult illiterate population (UIS, 2016). Of the 750 million adult (15+) illiterates in the world, 17 million are found in Latin America (see table 1d; UIS, 2016). In Latin America, findings suggest that there is no or little difference between male and female youth and adult illiteracy rates based on its gender parity index (GPI), which is 1.00 for both and 0.95 for the elderly (a GPI value between 0.97 and 1.03 is usually interpreted to indicate gender parity). Yet, by country, data shows that the majority of illiteracy rates in older adult females are above men in Mexico (20%), Peru (7%), Bolivia (3%) and Ecuador (3%; see table 1e, UIS, 2016). A report presented by the UNESCO estimates that the poorest young women in developing countries might not be able to achieve literacy until the year 2072 (UNESCO, 2014). Although there is a general consensus that a gender gap based in illiteracy rates is minimal, this is the contrary when it comes to indigenous people in Latin America, where 56% of women are considered illiterate versus 41% of men (Hanemann, 2005). Yet, in countries such as Bolivia and Peru, where there are a large number of indigenous populations female illiteracy rates are nearly three times higher than the rates for men (UNESCO, 2004).

Table 1d. Latin America Illiteracy rates among adults, youth and older adults by gender

Indicator	All Adults	Youth aged 15-24 years	Adults 24-64 years	Older Adults aged 65 and older
Illiterate population, Latin America	31 million (4.13%)	2 million (2%)	19 million (4%)	10 million (7%)
Illiterate population, Latin America (female)	17 million (55%)	765 thousand (2%)	10 million (52%)	6 million (60%)
Illiterate population, Latin America (male)	14 million (45%)	1 million (51%)	9 million (47%)	4 million (40%)

Note. Percentages presented are calculated from total global population. Percentages do not equal to 100

Table 1e. Percentage of illiteracy by gender in Latin America

Country	Youth Females	Youth Males	Adults Females	Adult Males	Older Adults Female	Older Adults Males
Argentina	0.10%	0.22%	1.53%	2.08%	2.38%	2.25%
Bolivia	0.04%	0.05%	2.35%	0.65%	2.83%	1.41%
Chile	0.07%	0.10%	1.30%	1.58%	2.05%	2.02%
Colombia	0.26%	0.55%	5.97%	7.32%	6.38%	7.18%
Costa Rica	0.02%	0.03%	0.24%	0.30%	0.30%	0.18%
Ecuador	0.09%	0.11%	1.96%	1.58%	2.77%	2.22%
El Salvador	0.06%	0.11%	2.12%	1.34%	1.88%	1.61%
Guatemala	0.65%	0.54%	8.81%	4.46%	4.11%	1.51%
Honduras	0.14%	0.32%	2.06%	2.16%	1.32%	1.44%
Mexico	0.66%	0.95%	16.69%	12.37%	19.79%	17.46%
Nicaragua	.38%	.64%	2.65%	2.48%	1.10%	1.28%
Panama	.05%	.05%	.50%	.41%	.41%	.56%
Paraguay	.05%	.10%	.65%	.55%	.78%	.71%
Peru	.21%	.19%	5.89%	2.18%	6.58%	2.54%
Uruguay	.01%	.03%	.07%	.14%	.12%	.19%

Venezuela	.15%	.31%	1.78%	2.15%	2.51%	2.29%

The demographic transformations that are taking place in Latin America are part of the process of economic and social change that the region has experienced in the last decades, and pose important challenges for the future. When a country faces problems of malnutrition, education, health, environmental deterioration, delinquency, violence, sexual abuse and rape, the origins of these are probably due to the lack of quality of education (Freire, 1996). Thus, the following sections will discuss several factors that are associated with illiteracy.

Factors associated with illiteracy

Illiteracy and poverty. One of the main characteristics of illiteracy is that it occurs in populations of low economic resources and poverty. Although income inequality in Latin America has fallen in recent years, and Latin America has achieved considerable success in reducing extreme poverty over the last decade, Latin America remains one of the most unequal regions in the world (Bárcena-Ibarra & Byanyima, 2016). In 2014 it was reported that the richest 10% of people in Latin America had collected 71% of the region's wealth (Bárcena-Ibarra et al., 2016). If this trend continues, in six years the richest 1% in the region will have accumulated more wealth than the remaining 99% (Bárcena-Ibarra et al., 2016). Poverty is a multidimensional concept, as it not only deals with economic aspects, but also the inclusion of non-material and environmental aspects. Sadly, the greatest consequence of illiteracy is the persistence of poverty and social inequality. In cases of extreme poverty, children have to work to contribute to family support (McEwan, 2004) or are only able to attend the first six years of primary education (which are the only years *required* in Latin America; SITEAL, 2015). On the other hand, it has also been noted that a good proportion of people who are illiterate live in remote/rural areas where education access may be even limited (Gardiner, 2008; Lopez & Valdes, 2010).

Interestingly, these are places where a greater number of indigenous groups usually live (Villalba, 2013). The occurrence of labor, specifically among indigenous children is almost four times higher than among non-indigenous children, while only 8.4% of non-indigenous children between the ages of nine and 11 years of age worked, 31.2% of indigenous children had to work (Gigler, 2009).

All over the world the indigenous population tends to suffer multiple forms of exclusion that stem from both historical factors such as colonization, as well as present day political, economic and social discrimination (Galabuzi, 2004; Hooker, 2005). Coming from indigenous populations has resulted in higher levels of poverty, illiteracy and lower life expectancy among these groups (Haneman, 2005). Of the 50 million indigenous people that live in Latin America, 11% make up the region's total population (Brea, 2003; Montenegro & Stephens, 2006). Yet, it should be highlighted that indigenous individuals are not always the minority in their countries, as is the case of Bolivia and Guatemala where more than half of the population are considered indigenous (UNDP, 2004). In this context, illiteracy can be considered a major problem that affects, above all, individuals who live in rural/remote areas, who can also be part of indigenous groups.

Illiteracy and Education. Another characteristic related to illiteracy, is the link that exists between the increase of basic education and the reduction of illiteracy rates (which can be said depends almost entirely on a state/government's action). As previously described, despite Latin America having made remarkable progress in the last decade in terms of increasing literacy levels among young individuals, still less than one-third of young individuals (43 milion of the 163 million youth that live in Latin America) aged 25 to 29 have not received some kind of education at college, university, or a higher technical school (ECLAC, 2016). A lack of basic education at a young age is not the only source of illiteracy; dropping out of school is also a major factor in raising its rates in many regions of the world, including Latin America (ECLAC, 2016). From an economic perspective, a lack of literacy and education have been shown to be significantly related to income (Riveros, 2005). For example, in Latin America, income and schooling are strongly correlated. Young people who do not complete at least their basic education (e.g., primary school) are less likely to obtain jobs in order to avoid poverty (Goicovic, 2002). While people who are *absolute illiterate*s and *functional illiterates* end their working lives with an average income similar to or slightly higher than that of their first years of employment, literate persons who reach lower secondary education (8 to 9 years of education) or complete their upper secondary education (11 to 12 years of education) end their working lives with an average income two to three times higher than that of their early years (Martinez, 2010). The income of those with higher education invariably surpasses that of people who are illiterates.

The problem with lack of education is that it is mostly seen among the most disadvantaged, where individuals from poor and vulnerable households drop-out of school earlier than their peers in better-off households increasing the problem of illiteracy (Solórzano-Benítez, 2007). It has been reported that the average number of years education in rural areas is 4.4 years, compared to 9.2 in urban areas (Torres, 2009). In addition, in many of these dissadvantaged areas, teaching does not meet the minimum requirements and, therefore, the benefits of learning are very scarce (Puryear, 2015), thus increasing the problem of illiteracy, too. For example, rural areas often suffer from low quality of education and are confronted with a shortage of teachers, and a lack of proper teaching materials and classroom equipment. To ignore this problem, is to conceal the true socioeconimic nature of its origins. For this reason, many literacy programs are fundamental for these individuals, which objective is to teach individuals how to read and write and, consequently, contribute to the socialization and integration to their community and society as a whole. For example, UNESCO's Education for All (EFA) aims to increase primary education, adult literacy, gender parity, and education equalty in the world (UNESCO, 2015).

With respect to education, it is worth mentioning how Latin America has still a long road to go in order to reach the educational standards of many parts of the developed world. For example, the results of the Program for International Student Assessment (PISA; a test comprised of three subject areas, math, science and reading, which 15-year-old students take every three years) revealed that Latin America and the Caribbean were again positioned at the bottom of the international ranking on education quality in all three-subject areas (OECD, 2016a). In science, for example, Latin America occupies the bottom third of countries, with Chile found in the 44th position, followed by Uruguay (47th position), Colombia (57th position), Mexico (58th position,) Brazil (63th position), Peru (64th position) and the Dominican Republic occupying the last position (70th position; OECD, 2016a). Similar rankings were seen for the mathematics and reading subject areas of the PISA (see Table 1f).

Table 1f. Raking Scores for Reading and Mathematics, PISA 2015

PISA, 2015 Ranking scores for reading and mathematics	
Ranking in Reading	Ranking in Mathematics
38 - CABA (Argentina)	42 - CABA (Argentina)
42 - Chile	48 - Chile
46 - Uruguay	51- Uruguay
51 - Costa Rica	53 - Trinidad and Tobago
52- Trinidad and Tobago	56 - Mexico
54 - Colombia	59 - Costa Rica

55- Mexico	61 - Colombia
59 - Brazil	62 - Peru
63 - Peru	65 - Brazil
66 - Dominican Republic	70- Dominican Republic

*Ranking 1 (best) to 70 (worst)

Illiteracy and employment. Although the economy in Latin America grew more slowly in 2011 than in 2010, there were some major improvements on the employment front. The unemployment rate fell from 7.3% in 2010 to 6.7% in 2011 (ECLAC, 2012). However, a group of individuals that still faces serious employability issues, given their low level of knowledge and expertise from lack or low education, are people who are illiterates. This disadvantage can be attributable to a lack of formal education, caused either by an early drop-out of school to enter the labour market or the loss over time of the ability to read and write (Hanemann, 2005; Martinez et al., 2010). For example, young individuals who fail to complete primary school have a lower chance of obtaining jobs of sufficient quality to avoid poverty (Goicovic, 2002). It is important to note that both the public sector and private companies now demand a high school diploma even for manual jobs, which is problematic in regions such as Latin America where fewer than one-third of its population do not complete secondary studies or even finishes high school (OECD, 2016b). For example, in a country like Mexico – the 11th largest economy in the world (Pariona, 2017) – still a little less than half (44%) of young individuals finish high school, (OECD, 2014), thus giving space for illiteracy to increase the negative effect on their future employment.

Among the employed population, people who are illiterate are the least likely to have an employment contract (Martinez et al., 2010), yet one study by the UNESCO found that having four years of education more than doubles the probability of having an employment contract in some countries in Latin America; and a substantial increase does occur for individuals who complete an upper secondary education (Martinez et al., 2010). In addition, individuals who are illiterate have little awareness of their rights and duties, and may thus be inclined to accept more hazardous, low-quality employment contracts (Martinez et al., 2010). In Latin America, around 46% of individuals are employed in the informal sector, that is the take jobs as laborers, street vendors, waste pickers, etc. (Martinez et al., 2010). Illiteracy, as a problem, reduces the income an individual could potentially obtain over the course of his or her working life. Lacking the necessary skills needed for more advanced jobs, people who are illiterate are basically limited from better-paying positions or jobs (Martinez et al., 2010). In some countries in Latin America, the unemployment rate tends to go upwards relatively as education decreases, with the opposite occurring only among individuals with five to seven years of education (Martinez et al., 2010). Thus, the impact of illiteracy on quality of employment, needs to be taken into consideration in order to eliminate not only a social problem but an economic one.

Illiteracy and Crime. Illiteracy per say, is not a direct cause of criminal behaviour, but low educational attainment (e.g., number of years of education) and crime have been know to be closely related (Klein, 1998; Colclough, Packer, Motivans, Ravens, Barry, & Buchert, 2005). More than 60% of all prison inmates and nearly 85% of juvelines who face trial in the juvenile court system, are functionally illiterate or have reading and writing skills below basic levels (Snowling, Adams, Bowyer-Crane, & Tobin, 2000). Those who are still illiterate upon release have a high likelihood of re-offending, which is a high cost to the economy in terms of maintaining prisons, administrating the courts and running the justice system (World Literacy Foundation, 2015). Education is commonly viewed as a human capital investment that increases work opportunities in the future and thus decreases crime participation. Studies have argued that educational attainment reduces crime levels because it increases the opportunity costs from expected costs of incarceration (Groot & van den Brink, 2010), others report that supporting high school completion programs can subsequently reduce crime (Fella & Gallipoli, 2014), while others report better schools tend to reduce delinquency rates and later felony conviction rates (Lochner, 2011). These reseach suggest that by investing in education (and its quality), can provide a more skilled and knowledgeable society, and significantly save on the social costs of crimes, which many people who are illiterates (or those with low educational attainemnt) might be involved.

Illiteracy and Health. Healthcare literacy has been defined as "the degree to which individuals have the capacity to obtain, process, and understand basic health information and services needed to make appropriate health decisions" (U.S. Department of Health and Human Services, 2000). A growing body of research exists concerning low literacy and its association with negative outcomes (DeWalt, Berkman, Sheridan, Lohr, & Pignone, 2004). These outcomes have been associated with more frequent hospitalization visits (Baker et al., 2002; Baker, Parker, Williams, & Clark, 1998), higher rates of health services utilization, higher prevalence of depressive and anxiety symptoms (Quintanilla & García, 2013; Kessler et al., 2003; Rowlands et al., 2013), poorer health (Weiss, Hart, McGee, & D'Estelle, 1992), both poorer mental and physical health (Lincoln et al., 2006), and worse prevention practices and less knowledge in people with chronic diseases such as diabetes (Rothman et al., 2004; Schillinger et al., 2002), heart disease (Müller Ricardi, 2003), asthma (Paasche-Orlow, Brancati, Rand, & Krishnan, 2003; Williams, Baker, Honig, Lee, & Nowlan, 1998), and cancer (Davis, Arnold, Berkel, Nandy, Jackson, & Glass, 1996; Scott, Gazmararian, Williams, & Baker, 2002; Sharp, Zurawski, Roland, O Toole, & Hines, 2002).

People who are illiterate or have very basic knowledge in reading and writing face great difficulties in understanding and, consequently, in putting into practice messages intended to promote healthy behaviors and risk prevention in different areas of daily life (Dexter, LeVine & Velasco, 1998). Research has also argued that there are limitations in the knowledge and practices surrounding self-care, especially in women, leading to problems in their health, hygiene and nutrition (UNESCO, 2006). The effects of illiteracy on the health dimension can be observed at home (in general and mother/child), at work and in their sexual and reproductive behavior.

Poverty, food insecurity, and *illiteracy* are the top three leading causes of malnutrition (Beal, Massiot, Arsenault, Smith & Hijmans, 2017). A low level of maternal education has been associated with poor feeding practices, leading to malnutrition (Tette, Sifah, Nartey, Nuro-Ameyaw, Tete-Donkor, & Biritwum, 2016). Women who are literate or who are participating in literacy programs have been found to have better knowledge and behaviors about health than women who are illiterate, which tend to have inadequate nutrition and hygiene practices in their home and they are also less likely to adopt preventive health measures such as vaccinations, health checks, among others (Burchfield, Hua, Iturry and Rocha, 2002; Galgamuwa, Iddawela, Dharmaratne, & Galgamuwa, 2017; UNESCO, 2006). For example, in Nicaragua infant mortality rates have been shown to decline in families whose mothers have participated in literacy programs and even more where they reach at least primary education (Sandiford Cassel, & Sanchez, 1995). In Bolivia it has been shown that literacy programs have a significant effect on the acquisition of good habits and knowledge concerning health care (Burchfield et al., 2002). Research has shown that girls with low levels of education have a higher risk of being malnourished; and girls who are malnourished have a higher probability of becoming malnourished mothers and, therefore, be at a greater risk of giving birth to low birth weight babies (Özaltin, Hill & Subramanian, 2010). However these babies/children are not only at increased risk of mental and physical underdevelopment due to malnutrition, but are also predetermined to be at a higher risk of cardiovascular diseases during their adult life (Khademi, & Jahanlou, 2015; Vorster & Kruger, 2007).

In relation to sexual and reproductive health, misinformation is one of the most important problems people who are illiterate experience. Among many things, being illiterate increases the likelihood of having high-risk sexual behavior, due to lack of knowledge about sexual and reproductive health and inappropriate use of contraceptive methods (Vandemoortele & Delamonica, 2000). Research has shown that higher education is related to a reduced risk of HIV infections (Glynn et al., 2004; Walque, Nakiyingi-Miiro, Busingye, & Whitworth, 2005). For example, a study among women in 32 countries showed that literate women are four times more likely to know ways to protect themselves against AIDS than people who are illiterate (Vandermoortele et al., 2000). A second study reported that men who engaged in unprotected sex had less education than more educated counterparts (Kelly et al., 1995). These findings indicate that AIDS/HIV prevention efforts are needed for men and women with a particular focused on the less educated individuals.

Moreover, people who are illiterate– depending on the job – have a higher probability for occupational accidents, which could be due to not understanding writen instructions when using certain machinery, or the safety rules necessary to comply in their daily tasks, thus putting their health and the rest of their colleagues at risk (ECLAC, 2005). Workplace illiteracy is difficult to detect since workers who are illiterate often become adept at concealing their deficiencies (Ford, 1992). Failure to use safety equipment increases the prevalence of occupational accidents, but also increases the likelihood of work-related injuries (e.g., Traumatic Brain Injuries, Spinal Cord Injuries, among others).

Many studies have shown that illiteracy and lower educational levels are major determinants for the prevalence of dementia and a major risk factor for cognitive decline (Anstey, Burns, Birrell, Steel, Kiely, & Luszcz, 2010; Contador, del Ser, Llamas, Villarejo, Benito-León, & Bermejo-Pareja, 2017; Jia et al., 2014; Teresi, Grober, Eimicke, & Ehrlich, 2012; Zhang et al., 1990). In Latin America it has been reported that Dementia prevalence is twice that of literate individuals (Nitrini et al., 2009). A number of factors have been found to be associated to higher prevalence of dementia among illiterate populations, such as low cognitive reserve, and poor control of cerebrovascular disease risk factors (Bonaiuto et al., 1990; Caramelli et al., 1997; Dartigues et al., 1991; Hill et al. 1993; Liu et al. 1994; Mortiner, 1988; Rocca et al. 1990; Stern, Gurland, Tatemichi, Tang, Wilder & Mayeux, 1994) which can lead to stroke, specifically in this population (Khedr et al., 2013; Wang et al., 2014). According to the cognitive reserve (CR) theory, education provides more efficient cognitive operations, which allows individuals to better manage brain damage, delaying the appearance of dementia (Amieva et al., 2014; Stern, 2006).

In conclusion, people who are illiterate are more likely than their literate couterparts to have lower quality of labor and medical problems which in turn are related to their physical and mental health. In addition, this population is at higher risk of suffering accidents and/or suffer from neurological disorders, thus increasing the probability of presenting cognitive and emotional alterations, and the need for health and psychological services, such as neuropsychological assesments, diagnosis and/or rehabilitation intervention.

Illiteracy and Cognitive Processes

The environment in which an individual develops is capable of generating anatomical and functional changes to brain structures (Yuste & Bonhoeffer, 2001). At the same time, cognitive functions reflect those changes that take place in the structures of the brain (Kolb & Whishaw, 1998). When comparing people who are illiterate and people who are literate, brain differences have been found to be a product of exposure to the learning processes associated with education and literary skills. In addition, the representation of spoken language is altered by the learning of reading and writing (Ardila et al., 2010, Ardila, et al., 2000, Ardila, Ostrosky-Solís, Rosselli & Gomez, 2000; Ostrosky -Solís, Ramirez & Ardila, 2004), corroborating that the brain adapts as it processes information from the environment.

Lateralization of brain function

Studies on brain dominance have shown mixed results on the similarities and differences in language organization in people who are illiterate and literate. For example, early studies conducted by Lecours, and colleague (1987a, 1987b, 1988) suggest that there is a greater involvement of the right hemisphere in linguistic functions in people who are illiterate than in those that are literate. This conclusion was determined by studying brain injured (left hemisphere) individuals who were illiterate and literate and observing that the classic aphasic syndromes occurred more severely in people who were literate than in people who are illiterate and with similar injuries. On the other hand, a group of researchers found no evidence of these differences when studying similar individuals with aphasia and brain injuries in the left hemisphere. These authors found that 63% of patients who are literate and 67% who are illiterate had aphasia (Damasio, Castro-Caldas, Grosso & Ferro, 1976a, Damasio, Hamsher, Castro-Caldas, Ferro & Grosso, 1976b).

A functional study using Positron Emission Tomography (PET) concluded that there are differences in areas of brain activation during linguistic tasks between people who are illiterate and literate. When asking participants to repeat words and pseudowords, it was observed that the areas of homologous activation in the parietal lobe were different between both groups. The upper areas of the parietal lobe were more active on the left side than on the right side in people who are illiterate, while the opposite occurred in the lower areas of the parietal lobe and the precuneus (Castro-Caldas, Petersson, Reis, Askelof & Ingvar, 1998). Another study conducted by Deloche, Souza, Braga, and Dellatolas (1999) used functional magnetic resonance imaging (fMRI) to evaluate brain activation while people who are illiterate and literate performed an approximation task of numerical magnitude. For example, one of the questions was to decide if 10 people inside a typical car represented a high, low, or average number. The results showed that people who were literate activated areas exclusively to the right hemisphere, including the frontal lobe, the inferior parietal lobe and the temporal lobe. On the other hand, areas in both hemispheres were activated in people who were illiterate, particularly in the temporal and occipital lobes. Participants who were illiterate expressed having used visual strategies when making the estimation, which may explain the activation of the occipital lobe, while literate participants used abstract thinking to solve the exercise (Ardila et al., 2010). According to Petersson, Silva, Castro-Caldas, Ingvar, and Reis (2007), these differences can be attributed to the possibility that lateralization is not a global phenomenon but a regional one and that the hemispheric differences that have been observed are dependent on the test that the individual is performing.

Neural and anatomical differences

A study by Jacobs, Schall, and Scheibel (1993) evaluated the morphology of dendrites in the Wernicke area associated with language comprehension in 20 right-handed subjects without neurological dysfunctions. These researchers found that as the level of education increased, the length of the neurons was greater. Several studies have suggested that the amount of white matter in the corpus callosum, which connects both hemispheres, is higher in people who are literate and thinner in people who are illiterate (Castro-Caldas, 2004, Petersson et al., 2007). The brain of people who are illiterate has developed without the experience of integrating the visual and motor systems with the system in charge of oral language, which seems to determine the interhemispheric connection (Castro-Caldas, 2004).

Cognitive Differences

Neuropsychology is a subfield of psychology that studies the relationship between brain functions and cognitive abilities in individuals and those with brain injuries (Lezak, Howieson, & Loring, 2004). An important characteristic of neuropsychology is the use of standardized tests that have as an objective to measure an individual's performance on different cognitive domains (e.g., executive functions, attention, memory, language, and visuospatial and motor skills; Lezak et al., 2004; Strauss, Sherman, & Spreen, 2006). Sometimes *norms* are developed when tests are standardized and scoring systems or baselines are created from a reference population that establishes a baseline distribution for a score or measurement, and against which the score or measurement can be compared. Typically, normative data is obtained from a large, randomly selected sample from a wider population. Normative data can also incorporate additional variables such as age and sex, when these variables are expected to have significant effects on the distribution of measurements (Campbell, 2013). For example studies have shown that cognitive performance on neuropsychological tests could be influenced by multiple factors such as age (e.g., Van Der Elst, Van Boxtel, Van Breukelen, & Jolles, 2005), sex (e.g., Miller, & Halpern, 2014), socio economic status (SES; e.g., Calvo, & Bialystok, 2014), language (e.g., Rosselli, Ardila, Lalwani, & Vélez-Uribe, 2016), and race/ethnicity (e.g., Castora-Binkley, Peronto, Edwards, & Small, 2013) among other factors, which is why tests are standardized. Therefore, below a number of studies are presented that show the impact of illiteracy in a number of cognitive functions.

Learning and visual memory, and visuospatial and visual motor skills. Several studies have investigated the nature of visuospatial perception in illiterate individuals (Ardila, Rosselli, & Rosas, 1989b; Matute, Leal, Zarabozo, Robles & Cedillo, 2000). Studies comparing people who are illiterate with highly educated subjects have showed significant differences according to education in this test (Ardila, et al., 1989b) and tests that measure similar cognitive abilities, such as the Clock Drawing Test (CDT; Nitrini et al., 2004) drawing a cube or two-tree dimensional figures (Ardila et al., 1989b; Dansilio et al., 2005; Hong et al., 2011) and the Draw-a-Map test (Ardila & Moreno, 2001).

One study reported that adults who are illiterate differed from literate adults, matched by sex and age, in all visuospatial tasks (copying a cube, copying a house, performing the ROCF, telling time on a clock, recognizing overlapping figures, and recognizing a national map; Ardila et al., 1989). Another study comparing a group of individuals who were illiterate and an educated group (6 and 7 years of education) in both a figure copying and constructional abilities found that the most frequent problem in individuals who were illiterate was the inability to reproduce the perspective and the unstructured copy (Dansilio and Charamelo, 2005). In addition, visually guided hand motor behavior may also be biased by education. In a test paradigm in which individuals who were illiterate and literate were asked to direct the cursor toward a target on the screen of a computer using a mouse, individuals who were illiterate were slower than the literate group, particularly when the right hand had to move the cursor to the left side of the screen, which is a crossed condition actually trained by learning to write (Reis et al., 1997).

The performance of people who are illiterate when copying figures in many ways look like those of preschool children (drawing from right to left), which is a pattern not commonly seen in children over the age of seven and subsequently in adults (Waber & Holms, 1985). In terms of directionality, a visuospatial effect of reading is training the direction of visual exploration (from left to right for most European writing systems. In regards to directionality, one visuospatial effect of reading is the training of direction of visual scanning (left to right, for most European writing systems). One study using nonlinguistic stimuli, studied the scanning mechanism through a computer target detection paradigm in subjects who were illiterate and literate and suggested that learning to read trains the scanning patterns toward more consistent scan paths (Ostrosky-Solís, Efron, & Yund, 1991). In addition, cognitive deficits of people who are functionally illiterate have also been reported. For example, one study found that people who were functionally illiterate performed significantly worse than literate individuals when it came to copying and remembering the ROCF, visual organization and visual memory, mental spatial orientation and in the tasks of sustained or divided attention (Van Linder & Cremer, 2008).

Many of the mistakes made by people who are illiterate are associated with poor planning and execution of hand motor behavior, particularly writing and drawing. For example, the CDT seems to be a very challenging test for people who are illiterate, since many of them are incapable of making any representation of a clock, which seems to be a skill highly dependent on education. CDT performance, like the ROCF, depends not only on visual skills, but also on cognitive processes such as semantic memory recovery, attention, receptive language, planning, organization, simultaneous processing and self-control directly or indirectly learned in school (Shulman, 2000). Learning to read reinforces certain fundamental abilities, such as visual memory, and visuospatial and visiomotor skills (Bramao, Mendonca, Faisca, Ingvar, Petersson, & Reis, 2007; Matute et al., 2000; Petersson, Reis, Askelof, Castro-Caldas, & Ingvar, 2000; Petersson, Reis, & Ingvar, 2001) thus is not surprising to see individuals who are illiterate to perform lower on these tests than their educated counterparts.

Executive Functions. Executive functions are a series of mental processes necessary when automatic responses to problems or environmental demands are no longer appropriate. These processes are known as working memory and cognitive flexibility, which lead to higher order cognitive processes such as metacognition and problem solving (Diamond, 2013). Education seems to influence formal operational thinking (Laurendeau-Bendavid, 1977), logical reasoning (executive functioning), functional brain organization (Castro-Caldas, et al., 1998, Ostrosky-Solis, Ramírez, Lozano, Picasso & Vélez, 2004) and the memory of the strategies that are the necessary skills to carry out successfully one of the most used tests to measure executive functions: the Modified Wisconsin Card Classification Test (M-WCST).

In spite of the popularity of the M-WCST in Latin America (Arango et al., 2016) a limited number of studies looking at the effects of illiteracy exist for individuals in this population. One study looking at executive functioning using the categories achieved in the card-sorting test (mental flexibility test) in children who were illiterate and literate, reported lower scores in the illiterate group suggesting that differences in the development of executive functions between these two populations was already marked in childhood (Ardila et al., 2010). One study using the M-WCST, found significant effects of education on groups with two years or less, three to nine years and ten years or more of formal education. The three groups had different performance to each other in correct categories and total errors. The less educated group (two years or less) had a significantly lower performance than the two more educated groups (Chan, Lam, Wong, & Chiu, 2003). A normative data study of for the M-WCST in a group of literate individuals from Latin America found that several of the scores in the M-WCST increased linearly in terms of education for most countries (Arango et al., 2015d). This pattern is supported by previous research where higher education is believed to be negatively associated with non-perseverative errors and perseverative errors (Obonsawin, Crawford, Page, Chalmers, Low, & Marsh, 1999), as well as positively associated with number of correct categories (de Zubicaray et al., 1998; Lineweaver, Bondi, Thomas, & Salmon, 1999).

Education is a variable that affects the deterioration of executive functioning related to age, in that higher education has been associated with more successful aging and lower education with worse age effects (Grigsby, Kaye, Shetterly, Baxter, Morgenstern, & Hamman, 2002; Van der Elst et al. 2006d). However, others consider that education is a poor predictor of executive performance (Hashimoto, Meguro, Lee, Kasai, Ishii, & Yamaguchi, 2006; Manly, Schupf, Tang, & Stern, 2005). For example, one study found that education ceased to have an effect on distraction errors after age 70, and the attentional focus on classification rules was more affected by age than by education (Plumet, Gil et al. Gaonac'h, 2005). Yet, it is also important to note that educational effects are not always linear, but rather curvilinear, tending to plateau. Research has shown that differences between 0 and 3 years of education are very significant; differences between 3 and 6 years of education are low; between 6 and 9 are even lower; and there are practically no differences after 12 years or more of education (Ardila, 1999).

Learning and verbal memory. Knowing how to read and write influences performance in verbal and non-verbal neuropsychological measures (Manly et al., 1999), therefore, people who are illiterate have a disadvantage in learning tests and verbal memory in comparison with those who are literate, even when some of them have years education. Memory processes in illiteracy have been investigated in several studies, however some have generated conflicting results. Individuals who are illiterate generally perform lower than schooled literates on neuropsychological memory measures such as wordlist learning and recall (Ardila et al., 1989b; Cole, Frankel, & Sharp, 1971; Cole, Gay, Glick, & Sharp, 1971; Folia & Kosmidis, 2003; Montiel & Matute, 2006; Nitrini et al., 2004). In most memory tasks, all memory measurements have proven to be very sensitive to level of education. The educational level, in comparison with other variables such as age and sex, has proved to be a very important variable (Ardila & Rosselli, 1989).

Studies report that individuals who were illiterate performed more poorly than individuals who were literate on measures of working memory (Morais, Kolinsky, Alegria, & Scliar-Cabral, 1998), as well as on measures of declarative memory, such as word list, delayed sentence recall, immediate and delayed short story recall, delayed verbal recall, immediate and delayed logical memory (Ardila et al., 1989b; Morais et al., 1998). In addition, people who are illiterate tend to perform worse than individuals who are semi-literate in most of the variables of the word-list learning test compared to literate people. More specifically, people who are illiterate perform worse in the first trial, delayed recall, recognition and semantic grouping than semi-literate people (Folia et al., 2003). More specifically, the group who was illiterate performed more poorly on the first -trial and delayed recall, recognition, and semantic clustering (Folia et al., 2003). These tasks are all done in artificial laboratory tasks which looks like skills trained in school; thus, putting individuals who are illiterate at a disadvantage. Individuals who are illiterate may not be accustomed to procedures learned through formal education and do not represent a kind of activity encountered in their day-to-day life.

Studies have revealed that culture and education influence the type of strategies used to remember information. An early study proposed that people who are illiterate use memorization more frequently (i.e., memorization by repetition), while those who are literate use more active information integration procedures ("meta-memory", Barltlett, 1932). People make use of specific mnemonic techniques, such as the reorganization of the material to be remembered, which can be linked to school learning experiences.

Verbal Fluency. Verbal fluency tests are frequently used in clinical and experimental evaluation due to its quick and easy administration. Verbal fluency tasks involve the production of as many words as possible in 60 seconds, starting with a certain letter/phoneme (phonological fluency) or belonging to a specific category such as animals, fruits, vegetables or professions (semantic fluency; Bryan & Luszcz, 2000; Parker & Crawford, 1992) and are often considered to be measures of executive functioning. However, several studies have reported that there is also a language component for these tasks (Henry & Crawford, 2004a; Henry et al., 2004b; Henry et al., 2004c; Whiteside et al., 2016). In particular, research has found that the educational level may influence verbal fluency since participants with fewer years of education generate a smaller number of words (Gonzalez da Silva, Petersson, Faísca, Ingvar, & Reis, 2004; Mathuranath, George, Cherian, Alexander, Sarma, & Sarma, 2003; Ratcliff et al., 1998).

Several studies report that the total production of words of people who are illiterate with respect to literate people is generally lower, mainly in phonological tasks. These could be due to difficulties with the explicit processing of phonological information, which seems to be a skill related to knowledge of grapheme-phoneme correspondence acquired indirectly with formal education (Kosmidis, Vlahou, Panagiotaki & Kiosseoglou, 2004) but also on semantic tasks (Kosmidis, Tsapkini, Folia, Vlahou, & Kiosseoglou, 2004; Manly et al., 1999; Ostrosky-Solis, Jaime & Ardila, 1998, Ostrosky-Solis, Ardila, & Rosselli., 1999; Petersson, et al., 2001; Ratcliff et al., 1998; Reis & Castro-Caldas, 1997). However, inconsistent results are often found in the literature when the effects of literacy are reported, specifically on semantic tasks. Studies comparing people who are literate and illiterate report that depending on the category applied during verbal fluency tasks, both groups may perform similarly or different. For example, when the "supermarket products" category is used, this word category seems to better reflect more appropriately the shared environment between both groups since both perform a significant amount of purchases in supermarkets (Reis, Guerreiro, & Petersson, 2003). However, when using a different category, such as “animals” literacy effects were evident. Several studies report how literate groups typically name more animals from within a range of subcategories, such as dinosaurs, kangaroos, or exotic animals (learned by reading) while illiterate groups can mainly name the animals with which they were most familiar, usually animals from the village where they grew up and/or from their immediate surroundings, such as horses, dogs, and cats (Brucki & Rocha, 2004; Gonzalez Da Silva, et al., 2004; Nielsen &Waldemar, 2016).

Research suggests that a likely explanation for these differences in literacy results is related to the particular choice of semantic category. A lower performance in semantic tasks (depending of the category used) is often a reflection of the limited access to different media information and communication, and possibly formal education. This difference goes to demonstrate that depending of the categorical task and the direct experience individuals have with this category, it could help facilitate performance. One study reported that when people who are illiterate are taught to read and write, their neuropsychological test performance improves, including for semantic tasks (Ardila et al., 2000b).

Summary

Literature has revealed some differences between different neuropsychological tests in within the illiterate population. A number of neuropsychological tests have been reported to be more sensitive to educational variables (e.g., verbal tests) than others (e.g., the WCST; Rosselli & Ardila, 1993). In general, individuals who are illiterate have a poorer performance on a number of different measures, such as language-related tasks (e.g., including word repetition [Lecours et al. 1987a; Reis et al., 1997], sentence repetition [Lecours et al. 1987b], semantic verbal fluency depending of the category [Gonzalez da Silva, et al., 2004; Nielsen, et al., 2016; Reis et al., 1997; Rosselli et al. 1990], verbal memory [Reis et al., 1997; Rosselli et al. 1990], and visual confrontation naming [Carraher, Carraher, & Schliemann 1982; Lecours et al. 1987a; Reis, Guerreiro & Castro-Caldas, 1994; Reis, Petersson, Castro-Caldas, & Ingvar 2001; Schliemann & Acioly 1989]). In addition to low performance on calculation tasks (Rosselli et al. 1990, Deloche, Souza, Braga & Dellatolas, 1999; Matute, Montiel, Pinto, Rosselli, Ardila, & Zarabozo, 2012), visual tasks (Ardila et al. 1989a; De Clerk 1976; Kolinsky et al., 1987), copying complex figures (Ardila & Rosselli 2003; Dansilio et a., 2005; Nielsen & Jørgensen, 2013) and constructional tasks (Matute et al. 2000). The majority of these differences could be partially explained due to tests being designed on an US educational system and in the learning opportunities of those abilities tested, which evidently do not represent people who are illiterate. For example, attending school can provide some content frequently included in neuropsychological tests (e.g., such as reading and writing). Studies where drawing skills are necessary, subjects who are not used to using a pen or pencil tend to hold the instrument in an awkward way and have trouble drawing straight lines. It may also be due to the fact that subjects who are illiterate are not test-wise; that is, they are not used to being tested and may not know how to behave in a test situation (Ardila et al., 2010).

Importance of having normative data

The majority of neuropsychological tests created have been standardized on individuals from Western, Educated, Industrial, Rich and Democratic (WEIRD; Henrich, Heine, & Norenzayan, 2010) backgrounds that are unrepresentative of the global human population. In a recent state of the field survey conducted in Latin America, neuropsychologists reported that the majority of tests used, lacked cultural adequacy and are made based on information and abilities taught in the American education system (Arango-Lasprilla et al., 2016) and therefore developed for individuals with high levels of education. It is not surprising that people who are illiterate underperform on cognitive tests that assess these particular abilities in which educated people were trained. It can also be extremely difficult to interpret test results from people who are illiterate as they are likely to perform like individuals with focal cerebral lesions or dementia on commonly used tests (Ardila, 1995; Dansilio & Charamelo, 2005; Youn, Siksou, Mackin, Choi, Chey & Lee, 2011), which could potentially increase the probabilities of diagnostic bias. Thus, not taking into consideration the variable of education, neuropsychologists can run the risk of assuming the existence of brain pathologies when there are only educational differences.

The wide use of neuropsychological tests during assessment is important to obtaining an accurate and objective measure of an individual's cognitive functioning in different domains, such as memory, attention, language, visuospatial skills, executive functioning, motor skills, and behavioral and emotional functioning (Lezak et al., 2004; Strauss et al., 2006). Thus, having normative data adjusted to specific sociodemographic (e.g., age, sex, education) and cultural characteristics of individuals is of great importance in order to adequately interpret an individual's score on a particular neuropsychological test (Lezak, et al., 2004; Strauss et al, 2006; Van der Elst, Molenberghs, Van Boxtel, & Jolles, 2013). It is also important to note that in Spanish-speaking countries, the main activities done by neuropsychologists are evaluation and diagnosis (88.9%, Arango-Lasprilla, et al., 2016). Yet, Latin American neuropsychologists also report that the majority of tests used do not have norms for Spanish-speaking children and adult populations (Arango-Lasprilla et al., 2016). For this reason, in recent years there have been a number of studies aimed to develop norms for individuals who are educated in Latin America (e.g., Arango-Lasprilla et al., 2015a; Arango-Lasprilla et al., 2015b; Arango-Lasprilla et al., 2015c; Rivera et al., 2015a; Rivera et al., 2015b; Rivera et al., 2015c; Rivera et al., 2015d; Rivera et al., 2015e; Peña-Casanova et al., 2009). However, to date, there are very few studies done with populations of adults who are illiterate. There is a great need to develop and implement neuropsychological tests for populations who are illiterate in all spheres of cognitive functioning (Ardila et al., 2010; Ardila & Rosselli, 1989a, Lecours et al., 1987a; Lecours et al., 1987b; Lecours et al., 1988; Rosselli, Ardila & Rosas, 1990).

The tests and questionnaires that professionals use must comply with suitable psychometric properties, such as reliability, validity and normative data (Strauss, Sherman & Spreen, 2006). Having normative data are intended to determine the performance of an individual in a test, comparing their scores with a reference sample comparable to the population from which the individual comes. The direct scores obtained in a test must be transformed to some type of distribution model, which allows determining the location of the person evaluated within the distribution, thus facilitating the process of interpreting the scores (Crawford, Venneri, & O'Carroll, 1998).

Different methods exist to generate normative data in neuropsychological tests, such as the direct conversion of raw scores to different metric scales such as *Z* values or *T* values (e.g., Schretlen, 2010; Golden, 2010; Rey, 2009), estimation of the mean and standard deviation for each subgroup of the adjustment variable (e.g., age ranges and education), the latter being the most used. Despite its high use, this method has two major limitations widely described by Van Breukelen, and Vlaeyen (2005). The first limitation is that normative data tables are generated assuming that the predictive variables of the test scores are known, that is, normative data are generated according to traditional demographic variables (e.g., age, sex, education) without examining if these are relevant for the correction of normative data. For example, normative data generated by sex may not be important for a test if this variable does not influence its performance.

The second limitation makes reference to the size of the sample used to generate normative data. Suppose you want to generate normative data adjusted to two demographic variables (e.g., sex and age). To do this, the sample is divided into subgroups, which implies a considerable loss of information. For example, when dividing the sample by sex (men vs. women), the sample size is reduced by approximately 50%. In addition, if the sample is divided into five age groups, the sample size is reduced by subgroup to 10% of the total sample. As a result, the distribution of test scores, including their mean and standard deviation, are not reliable since they can lead to random trends in the norm tables, where the average can vary and make large jumps within age groups.

Normative data with populations who are illiterate

Despite recent publications of normative data for neuropsychological tests based on multiple linear regressions for Latin American Spanish-speaking population (e.g., Olabarrieta-Landa et al., 2015a; Rivera et al., 2015a), all of them have concentrated on educated populations and, unfortunately, there are very few normative data for illiterate population. As of knowledge and literature search performed in 2018, only 11 normative studies *include* individuals who are illiterate in their studies (see Table 1g), implying norms for people who are *only* illiterate does not exist. The majority of these studies: include individuals who are illiterate together with a wide range of years of education (e.g., 0-3 years of education [Cavaco et al., 2013]); are in different languages (e.g., Portuguese [Leite, Miotto, Nitrini, & Yassuda, 2017]), are limited to one geographic area (e.g., Mexico [Ostrosky-Solís, Gómez-Pérez, Matute, Rosselli, Ardila, & Pineda 2007], San Diego [Gladsjo, Schuman, Evans, Peavy, Miller & Heaton, 1999]), are aimed for older people (Contador et al., 2016) and include small sample sizes of individuals who are illiterate (e.g., 32 [Kim & Na, 2004]), meaning normative data for individuals who are illiterate in Latin America does not exist. To better describe the available literature on normative data with this population, the next table provides a summary of this information (see Table 1g).

Table 1g. Summary of Published Normative Data with Illiterates

Reference	Language	*N*	Sex	Illiterates (*n*)	Location	Stratified age	Stratified Education	Neuropsychological tests
Ostroski-Solis et al. (1999)	Spanish	800	53% female	193	Mexican republic (Mexico City, Colima, Toluca, Morelos, and Oaxaca)	16 to 30, 31 to 50, 51 to 65 and 66 to 85	0 years of school, 1 - 4 years, 5 - 9 years and 10 or more years	NEUROPSI: Orientation, Attention, Encoding, Language, Conceptual Functions, Conceptual Functions and Recall
Kang et al., (2015)	Korean	888	72.1% female	164	Korea	60-64, 65-69, 70-74, 75-80, and ≥80 years	0–3, 4–6, and ≥7 years	Literacy Independent Cognitive Assessment (LICA)
Ostrosky-Solís et al., (2007)	Spanish	521	n/a	146	Mexican republic (Mexico City, Colima, Guadalajara and Zacatecas)	6–7, 8–9, 10–11, 12–13, 14–15, 16–30, 31–55, 56–64 and 65–85 years	0 to 3 years of education, 4–9 years of education and 10–22 years	NEUROPSI: Orientation, Attention and concentration, Executive functions, Working memory, Immediate memory, Delayed memory
Del Ser et al., (2004)	Spanish	368	49.5% female	30	South of Madrid	71-75, 76-80, 81-85 and > 86	Less than 4 years of formal education and four or more years of education	Short Portable Mental Status Questionnaire, MMSE, Benton Orientation Test, Bell Test, Verbal Fluency, Clock Drawing Test, Trail Making Test, Free and Cued Figures Recall, Logic Memory, Naming, incidental Recall, Delayed Recall, Similarities, IQCODE Questionnaire Of Jorm and Depression Questionnaire CES-D
Gutierrez et al., (2006)	Spanish	2,011	61% female	368	Mexican Republic (Mexico City, Colima, Guadalajara and Zacatecas)	Children: 6-7, 8-9, 10-11, 12-13 and 14-15; Adults: 16-30, 31-50, 51-65, 66-75 y 76-96	People who are illiterates, 1-4, 5-9, 10-24 years	Semantic Fluency task (animal category)
Cavaco et al., (2013)	Portuguese	949	67% female	53 had less than three years of education	Portugal	18-29, 30-39, 40-49, 50-59, 60-69, 70-79, >90	0-3, 3, 4, 5-9, 10-12, >12	two verbal fluency measures: the semantic fluency test (animal's category) and the phonemic fluency test (letters M, R, and P
Leite et al., (2017)	Portuguese	180	77.2% female	60	São Paulo, Brazil	60–69 years, 70–79 years, and ≥ 80 years	0 year (illiterate), 1–2 years, and 3–4 years of education	Boston Naming Test (BNT)
Brucki et al., (1997)	Portuguese	336	53.7% female	47	Brazil	Young and old	Illiterate, low, medium and high	Mini-Mental State Examination and VF (animals)
Kim et al., (2004)	Korean	224	57% female	32	Korea	15–74, and 75 years or older groups	0, 1–6, and 7 years or more	The Western Aphasia Battery, hereinafter K-WAB
Gladsjo et al., (1999)	United States	768	48% female	103 has less than 11 years of education	San Diego	20-34, 35-49, 50+	0-11, 2-15 and 16+	VF (FAS and Animals)
Contador et al., (2016)	Spanish	2,744	56.9% female	275	Spain	67-74, 75-79, 80-84, 85+	Primary school, Secondary/higher and Illiterates	Semantic Verbal Fluency

In is important to develop and standardize neuropsychological tests for Latin American populations, given that when these tests are developed in other countries and used in Latin America, these measures are frequently just translated and inaccurate norms developed in the originating countries/locations are used. In addition, given the influence education has on cognitive performance as seen in the literature (Ardila, Rosselli, & Ostrosky-Solis, 1992; Lecours et al., 1987a; Ostrosky, Canseco, Quintanar, Navarro, Meneses, & Ardila; 1985) norms used with Latin American populations should represent individuals with different educational levels, including individuals who are illiterate.

Objective

As part of the solution to the limitations from traditional methods commonly used to create normative data, the present dissertation proposed the development of demographic-adjusted norms based on multiple linear regressions and residual values generated for four commonly used neuropsychological tests in a group of adults who are illiterate from Latin America. To date, this is the first study to develop norms that include appropriate age-adjustments for the illiterate population in Latin America and will allow clinicians to more accurately interpret their performance.

Method

Participants

The sample of this study is part of the multicenter study for the standardization of a battery of neuropsychological tests in Latin America. The procedure followed in the project can be found in Guàrdia-Olmos, Peró-Cebollero, Rivera, and Arango-Lasprilla (2015). In the articles resulting from the multicenter study, individuals with zero years of education were excluded, however, those subjects were included as part of this dissertation. A group of 407 individuals from nine Spanish-speaking countries in Latin America were part of the present study. The inclusion criteria were: a) being between 18 to 95 years of age; b) being born and currently living in the country where the study was conducted; c) speaking Spanish as their native language; d) not having any years of education (self reported); and e) knowing or not knowing how to read and write.

The exclusion criteria were: a) having more than one year of education; b) having a history of a central nervous disease (e.g., stroke, epilepsy, movement disorders, multiple sclerosis, severe head trauma, and brain injury etc. via self-report); c) having some type of active or uncontrolled systemic disease associated with cognitive impairment (e.g., diabetes mellitus, hypothyroidism, vitamin B12 deficiency); d) having history of alcohol abuse or other psychotropic substances (self-report); e) having a history of psychiatric illness (e.g., bipolar disease, major depression, psychosis); f) having severe sensory deficits (e.g., auditory and/or visual loss) that could affect the participants' performance or the administration of these tests; g) using of psychiatric or other drugs that could affect one's cognitive performance; h) taking medications for chronic pain (e.g., Monoamine Oxidase Inhibitors – MAOI); and i) <23 on the MMSE (Folstein, et al., 1975; Ostrosky-Solís, et al., 2000; Villaseñor, et al., 2010), j) scoring >4 on the PHQ-9 (Kroenke, et al., 2001), and k) scoring <90 on the Barthel Index (Mahoney et al., 1965).

A total of 407 individuals were assessed. Of these 2 scored <23 on the MMSE (exclusion criteria i), and 3 scored <90 on the Barthel Index (exclusion criteria k). As requested by the dissertation committee, a total of 14 subjects were deleted due to a lack of country representativeness (Guatemala, n=8; Puerto Rico, n=5; and Peru, n=1). Thus, the final sample for analysis was 388 individuals who met all inclusion criteria. Of the final sample, 58.5% of the sample reported being absolute illiterates (i.e., does not know how to read/write and have zero years of education; n=227). The majority of participants were female (59.3%) and the mean age was 60.92 years (*SD*=18.50; range 18– 93 years). More than half of the participants were married or cohabited with a partner (n=207; 53.4%) and less than half came from rural areas (n=158; 40.7%). See table 2a for more socio-demographic characteristics of the sample.

Table 2a. Socio-demographic characteristics of the sample

		Frequency	Percentage	Frequency from original study*	Percentage from original study *
Sex	Female	230	59.30%		
	Male	158	40.70%		
Age	18 to 55 years	108	27.80%		
	56 to 75 years	177	45.60%		
	>76 years	103	26.50%		
Residential A	Urban	230	59.30%		
	Rural	158	40.70%		
Marital Statu	Married/Cohabitation	207	53.40%		
	Widowed	80	20.60%		
	Single	69	17.80%		
	Separated/Divorced	29	7.50%		
	Other	3	0.80%		
Handedness	Right handed	368	94.80%		
	Left handed	17	4.40%		
	Ambidextrous	3	0.80%		
Bilingual	No	352	90.70%		
	Yes	16	4.30%		
Absolute illiterates	Does not Read + Write + 0 years of education	227	58.50%		
Functional illiterates	Does Read + Write + 0 years of education	161	41.50%		
Country	Colombia	174	43.30%	1,425	26.37%
	México	89	22.10%	1,300	24.06%
	El Salvador	42	10.40%	257	4.75%
	Honduras	32	8.00%	184	3.40%
	Ecuador	26	6.50%	-	-
	Bolivia	25	6.20%	274	5.07%

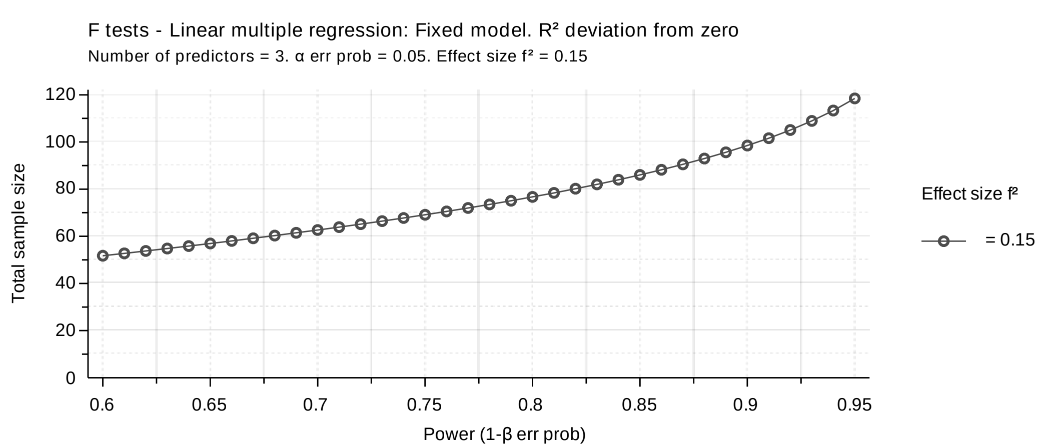
* Ecuador only participated in the second part of the study (normative data for individuals who are illiterate)

Sample size and power analyses

The sample size was estimated for convenience and was set at a total of 388 participants. With this sample size psychometric analysis of the tests can be made (Barrett & Kline, 1981, Comrey & Lee, 1992; Kline, 1979; Kline, 1994; Pearson & Mundfrom, 2010) to subsequently calculate normative data in neuropsychology (Bridges & Holler, 2007). Several of the most frequently cited guidelines suggest sampling at least 100 subjects (50 – very poor, 100 – poor, 200 – fair, 300 – good, 500 – very good, and 1,000 or more – excellent).

In the social, behavioral, and biomedical sciences power analyses are of great importance. The G*Power 3.1 program, which was designed as a general stand-alone power analysis program for statistical tests regularly used in social and behavioral research (Erdfelder, Faul, & Buchner, 1996) was used to find out the suggested total sample size needed in this study. Using a priori power analyses (Cohen, 1988), our sample size *N* was computed as a function of the required power level (1- ß), the pre-specified significance level and the population effect size to be detected with probability 1- ß. A linear multiple regression, with three as number of predictors and an effect size of 0.15 were specified to calculate the sample size for this study. According to the G*Power 3.1 program the study needed a minimum total sample size of at least 161 participants in order to reach a power of .99 (see Figure 2, for a visual representation).

Figure 2. Graph of estimated sample size using G*Power 3.1



Measures

Initially, and in order to determine whether participants met the inclusion and exclusion criteria, following informed consent, participants were given a socio-demographic questionnaire and three screening tests. Spanish versions of all neuropsychological and screening tests used in this study were available and have been used with Spanish-speaking populations.

Sociodemographic-clinical questionnaire

In order to collect information related to the health status and clinical history of the participants, a list of questions was designed in which relevant information about the clinical aspects of the participant was reflected. In the questionnaire the following information was obtained: demographic data (e.g., age, income, occupation), personal background, motor, language, visual and auditory problems; assistance received by different professionals (e.g., neurologist, psychiatrist, occupational therapist, speech therapist, psychologist) and the existence of psychological disorders or psychiatric illnesses and pharmacological treatment.

Screening tests

The three screening tests were: 1) the Mini Mental State Examination (MMSE, Folstein et al., 1975), 2) the Patient Health Questionnaire (PHQ-9, Kroenke et al., 2001) and 3) Barthel Scale (Mahoney & Barthel, 1965). The purpose of the screening tests were to determine the general cognitive status of the participant, depression levels and functional status through activities of daily living.

1) Mini Mental State Examination (MMSE, Foltein et al., 1975): The MMSE is a 30-item screening test that requires only 5-10 minutes to administer and focuses only on the cognitive aspects of mental functions, and excludes questions concerning mood, abnormal mental experiences and form of thinking. The MMSE evaluates cognitive functioning and is sensitive to

deterioration. The test is divided into two sections, the first one, which involves oral responses only examines orientation, memory, and attention. The second part examines an individual's ability to name, follow verbal and written commands, write a sentence spontaneously, and copy a complex polygon. Each category has different points assigned, for a maximum score of 30 points. Total scores range from 0 to 30 with lower scores indicating poorer cognitive functioning. Any score greater than or equal to 24 points indicates normal cognitive functioning. Below this, scores can indicate mild (19-23), moderate (10-18) and severe (≤9 points) problems in cognitive functioning. The cutoff of ≥23 used in this study was used to make sure participants had no cognitive impairments.

Several studies have reported the psychometric properties of the MMSE over the years, with an internal consistency ranging from 0.54 to 0.96 (e.g., Albert & Cohen, 1992; McDowell, Kristjansson, Hill & Herbert, 1997; Tombaugh & McIntyre, 1992) and correlations of 0.70 to 0.90 between MMSE scores and other measures of cognitive impairment, providing evidence for good reliability and construct validity (Castro- Costa, Dewey, Uchôa, Firmo, Lima- Costa, & Stewart, 2014; Tombaugh et al., 1992).

2) Patient Health Questionnaire (PHQ-9; Kroenke et al., 2001): The PHQ-9 is a nine-item self-report measure that evaluates the presence of major depressive disorder based on the criteria of the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV-R). Total scores for the PHQ-9 can range from 0 to 27, and each of the 9 items can be cored from 0 (not at all) to 3 (nearly every day). Scores with higher scores reflect higher levels of depression (1 to 4 =no depression, 5 to 9 =mild depression, 10 to 14 =moderate depression, 15 to 19 =moderately severe depression, and 20 to 27 =severe depression). The cutoff of ≤4 used in this study was chosen to make sure participants had no depression.

Reliability and validity of the PHQ-9 have indicated it has good psychometric properties. The internal consistency of this test has been shown to be high; with Cronbach alphas ranging from 0.83 to 0.89, (Chagas et al., 2013; Gelaye et al., 2013; Kroenke & Spitzer, 2002; Kroenke et al., 2001) and adequate reliability with correlation coefficients ranging from 0.63 to 0.73 between the PHQ-9 and the other neuropsychological tests (Bian, Duan & Wu, 2011; Chagas et al., 2013; Kroenke et al., 2001; Martin, Rief, Klaiberg & Braehler, 2006). The PHQ-9 reliable and valid measure of depression severity makes it a useful tool for both clinicians and researchers.

3) Barthel Scale (Mahoney & Barthel, 1965): The Barthel Scale is a measure that assesses performance in activities of daily living (ADL). It uses ten variables describing ADL and mobility (presence or absence of fecal incontinence, urinary incontinence, help needed with grooming, toilet use, feeding, transferring from place to place, walking, dressing, climbing stairs and bathing). Each individual's ability to perform these activities is given a score of 0, 5, 10 or 15 points. The overall range varies between 0 (completely dependent) and 100 points (completely independent). The cutoff of ≥90 in this study was used to make sure participants did not had any physical dependence problems (Barthel Index; Mahoney, et al., 1965).

The Barthel Index test has received good reliability ratings. The 10-item test has shown an internal consistency of 0.87 to 0.92 (Hsueh, Lee, & Hsieh, 2001; Shah, Vanclay, & Cooper, 1989). Correlated with other cognitive measures, the Barthel Index has shown adequate correlations of 0.73 to 0.94 (Hsueh et al., 2001; Shah et al., 1989), showing to be a reliable and valid instrument for clinicians and researchers.

Subsequently, those who met inclusion criteria were given a series of four neuropsychological tests listed below:

Neuropsychological tests

Rey–Osterrieth Complex Figure (ROCF; Rey, 2009). The ROCF, developed in 1941 by Rey, and revised by Osterrieth in 1944, is a figure made up of a series of complex of rectangles, lines, circles, triangles, and other geometric components (Rey, 1941). The ROCF is one of the ten most used neuropsychological tests at present (Camara, Nathan & Puente, 2000; Knight & Kaplan, 2003; Olabarrieta-Landa et al., 2016b; Rabin, Barr & Burton, 2005). Its popularity is due to the fact that it allows the evaluation of several cognitive processes, which include planning, organizational skills and problem-solving strategies, visuoconstructive praxias and visual, motor and episodic memory (Beltrán Dulcey & Solis-Uribe, 2012; Meyers & Meyers, 1995a; Waber & Holmes, 1986). The test is divided into two parts: the first part consists of copying the ROCF by hand, and the second in reproducing the figure from memory three minutes later (Rey, 2009) or 45 minutes (Knight & Kaplan, 2003; Mitrushina, Boone, Razani & D'Elia, 2005; Rey, 1941). Osterrieth (1944) standardized the scoring procedure of 18 items and 36 points we use today. In this system, the figure is divided into 18 elements and each element is given a score between 0 and 2 points depending on accuracy, distortion, and location of its duplication; 36 is the maximum score which represents better functioning (Rey, 2009). Both the quality and the position of the elements in the copy are evaluated. With regards to the test's psychometric properties, reliability of the test has been demonstrated in several studies: Tupler, Welsh, Asare-Aboagye and Dawson (1995) present an inter-evaluator reliability of 0.85 in copy and 0.97 in memory. On the other hand, Prieto, Delgado, Perea, and Ladera (2010) present a reliability (Cronbach α) of 0.83 in a sample of healthy controls and 0.84 in patients with traumatic brain injury.

Different studies have shown a number of variables that can influence the performance of the test, for both copy and memory. For example it has been shown that the scores of the ROCF increase with age, slowing down between 12 and 16 and reaching adult levels at 17 (Arango-Lasprilla et al., 2017; Meyers & Meyers, 1995b). The scores tend to decrease with advancing age, especially in individuals who are over 70 years of age (Chiulli, Haaland, Larue & Garry, 1995; Lannoo & Vingerhoets, 2004; Ostrosky-Solis, et al.,1998; Rivera et al., 2015a; Rosselli & Ardila, 1991). On the other hand, the influence of gender is controversial. Some studies show men score higher than women (Caffarra, Vezzadini, Dieci, Zonato & Venneri, 2002; Kramer & Wells, 2004; Rivera et al., 2015a), even though these differences are small and inconsistent between studies (Demsky, Carone, Burns & Sellers, 2000; Rivera et al., 2015a; Tombaugh, Faulkner & Schmidt, 1992). Strauss et al. (2006) suggested that ambiguous and contradictory findings might reflect individual variability and differences within each sex. As far as education, studies show that scores for the ROCF increase linearly (Caffarra et al., 2002, Lannoo et al., 2004; Pontón et al., 1996, Rivera et al., 2015a). However, some authors report the ROCF scores are not affected by education and/or by general intelligence (Chervinsky, Mitrushina & Satz, 1992; Delaney, Prevey, Cramer & Mattson, 1992; Diaz-Asper, Schretlen & Pearlson, 2004; Tombaugh et al., 1992).

The ROCF test is sensitive to a number of neurological disorders (Machulda et al., 2007). This test has been used to examine cognitive problems in patients with brain injuries (Ashton, Donders & Hoffman, 2005; Berry, Allen & Schmitt, 1991; Poulton & Moffitt, 1995), Alzheimer's disease (Ardila et al., 2000a; Berry et al., 1991, Freeman et al., 2000; Tei, Miyazaki, Iwata, Osawa, Nagata & Maruyama, 1997), Parkinson's disease (Cooper, Sagar, Jordan, Harvey & Sullivan, 1991; Freeman et al., 2000), Huntington's disease (Fedio, Cox, Neophytides, Canal-

Frederick & Chase, 1979), and schizophrenia (Calev, Edeist, Kugelmass & Lerer, 1991; Knight, Sims-Knight & Petchers-Cassell, 1977, Silverstein, Osborn & Palumbo, 1998).

Normative data studies with the ROCF have been limited. For example, Caffarra et al. (2002) collected normative data in a large Italian sample, between the ages of 20 and 89 years. Rosselli and, Ardila (2003) developed normative data for Spanish speakers in Bogotá, Colombia, based on a sample of 624 children and adults. Strauss et al. (2006) developed normative data for Canadian children and adults between the ages of 6 and 70 years. In 2009, Peña-Casanova and colleagues (2009) provided normative data for the ROCF for 356 Spanish individuals between the ages of 50 and 90 years. A few years later within the same research group, Palomo et al. (2013) provided normative data for a younger Spanish population, between the ages of 18 and 49 years. More recently, Rivera et al. (2015a) developed normative data for a Spanish-speaking population in 11 Latin American countries, bringing together a total of 3,977 adults between 18 and 95 years of age.

There are a number of limitations in these studies. On one hand, each study uses different times for the second part of the test (recall/memory). In the study carried out by Caffarra et al. (2002), the recall of the figure was done at 10 minutes and Rivera et al. (2015a) at 3 minutes. In the studies by Peña-Casanova et al. (2009) and Palomo et al. (2013) two different times were used, the first was at 3 minutes and the second at 30 minutes. The results of these studies cannot be generalized to all populations. It should be noted that to date there has been no normative studies in people who are illiterate based on multiple linear regression models for the ROCF test.

The Modified Wisconsin Card Sorting Test (M-WCST; Nelson, 1976; Schretlen, 2010). The Wisconsin-Modified Card Classification Test (M-WCST) is a modified version of the Wisconsin Card Sorting Test (WCST). The M-WCST is a widely used neuropsychological test for assessing higher-order cognitive functioning, and as a measure of executive functions, given that it implies the use of working memory, planning, attentional flexibility and inhibition in the resolution of new problems (Schretlen, 2010).

The M-WCST consists of four stimuli cards and 48 response cards; each stimuli card represent a figure that varies in shape (cross, circle, star or triangle), color (yellow, red, green or blue) and number (one, two, three or four). The evaluated person is asked to match the response cards with the four key cards. The objective of the task is for the person being evaluated to generate, tests and modify strategies in order determine the classification principle that underlies the placement of the key card, based on the information the evaluator indicates (whether or not its placement is correct and if the classification principle has changed). The test ends when the participant manages to classify 6 categories correctly or when the 48 cards are used. The scores that can be obtained are the number of correct categories, total number of errors, and number and percentage of perseverative errors (Greve, 2001; Schretlen, 2010). Regarding the psychometrics of the M-WCST, Bird, Papadopoulou, Ricciardelli, Rossor, & Cipolotti, (2004), presents reliability of the test in a study with 188 healthy volunteers aged between 39 and 75 years of age. The correlation coefficients of the test-retest show significant values between the two application of both the total number of errors, and the number of perseverations (r's>0.34; p's<0.01). Moreover Schretlen et al. (2007) presents a Cronbach's alpha of 0.829, showing optimum reliability of the test.

The M-WCST has been used in the evaluation of individuals with major depressive disorders (Cotrena, Damiani, Milman & Fonseca, 2016, Gohier et al., 2009), Alzheimer's (Bertoux et al., 2013, Salmon et al., 2015), Parkinson's disease and mild cognitive impairment (Auffret et al., 2017; Petrova, Raycheva, Zhelev & Traykov, 2010), ADHD (He et al., 2015), Huntington's disease (Peinemann, Schuller, Pohl, Jahn, Weindl & Kassubek, 2005), damage to the frontal lobe (Yeh, Tsai, Tsai, Lo & Wang, 2017), obesity (Puig et al., 2015), anorexia nervosa (Fassino, Pieró, Daga, Leombruni, Mortara, & Rovera, 2002), head trauma (Fork, Bartels, Ebert, Crubich, Synowitz & Wallesch 2005) and schizophrenia and bipolar disorders (Chang, Hui, Chan, Lee, Wong, & Chen, 2014; Cotrena et al., 2016).

Regarding the standardization of the M-WCST, there are several studies that provide us with normative data, however no studies have looked at individuals who are illiterate. For example, in a study conducted by Caffarra et al. (2004), normative data can be found for a sample of 148 people between the ages 20-90 years and with five to 13 years or more of education. Schretlen (2010) provides norms for a sample of English speaking individuals, between the ages of 18 and 92, and at least 3 years of formal education. In a study by Obonsawin et al. (1999) normative data is provided for a sample of English adults between the ages 16 to 75 and with 8 to 20 years of education. Lineweaver, Bondi, Thomas and, Salmon (1999) provide normative data for a sample of healthy adults and older Americans between the ages 45 and 91 with 1 to 20 years of education. Wang et al. (2011), provides norms for a Chinese population between the ages of 16 and 75 years with 1 to 23 years of education, and Zimmermann et al. (2015) for a Brazilian population, between the ages 19 and 75 with at least 5 years of formal education. More recently, norms have been published for the M-WCST in a sample of 5,379 individuals from 12 countries in Latin America with 1 to 25 years of formal education (Arango-Lasprilla et al., 2015d; Rivera et al., 2015). The M-WCST is a test widely used in research, which currently has normative data for people from different countries, age rages and levels of education. However, to date there have been no studies of such scale in people who are illiterate.

Hopkins Verbal Learning Tests- Revised (HVLT-R; Brandt & Benedict, 2001). The HVLT-R is a brief test that measures verbal learning and memory. There are six different forms of the HVLT-R, in order to reduce measurement errors associated with practice (Vanderploeg, Schinka, Jones, Small, Borenstein-Graves, & Mortimer, 2000). The form used in this study was number five, which consists of a list of 12 words extracted from 3 different semantic categories (i.e. professions, sports and vegetables). The 12 semantically categorized words are read to the participant in three separate free recall learning trials, the first one is an immediate recall, followed by a 25 minute delayed recall trial, and ending with a yes or no recognition trial. The last recognition trial includes a list of 24 words, incorporating 12 from the original recall list, six words that are semantically associated to the recall items but that were not included in the beginning trial, and six unrelated words.

When scoring the HVLT-R, the examiner must record the words remembered in each attempt. The HVLT-R offers three scores: (1) the total recall, which is the sum of the number of words correctly remembered in attempts 1, 2 and 3; (2) The delayed recall, which corresponds to the number of correctly recognized words after 25 minutes; and (3) The recognition trial, which corresponds to the number of correctly recognized words when adding six words that are semantically associated to the recall items but that were not included in the beginning trial, and six unrelated words (Strauss et al., 2006). Concerning the reliability and validity of the HVLT-R, the authors estimated the test-retest reliability in a sample of elderly individuals, obtaining coefficients within the limits accepted for the three learning trials (*r's*=0.41) and calculated the construct validity of the measures for learning and recovery (Benedict, Schretlen, Groninger & Brandt, 1998). Other authors have provided evidence of convergent validity (Woods et al., 2005a; Lacritz, Cullum, Weiner, & Rosenberg, 2001) concurrent (Shapiro, Benedict, Schretlen & Brandt, 1999), and discriminant validity (De Jager, Hogervorst, Combrinck, & Budge, 2003).

The HVLT-R has been used for the evaluation of memory in patients with Alzheimer's disease (Gaines, Shapiro, Alt & Benedict, 2006; Kuslansky et al., 2004; Lacritz et al., 2001), tumors (Okoukoni et al., 2017), head injuries (Echemendia & Julian, 2001), bipolar disorders (Van Rheenen & Rossell, 2014), vascular dementia (Gaines et al., 2006; Kuslansky et al., 2004), multiple sclerosis (Chiaravalloti, DeLuca , Moore & Ricker, 2005), HIV (Woods et al., 2005b) and methamphetamine dependence (Woods et al., 2005a), among others.

There are different variables that have been shown to influence the performance of the HVLT-R. Most studies have shown that age and education are the main predictors of performance in the HVLT-R (Arango-Lasprilla et al., 2015e; Cherner et al., 2007; Duff, 2016; Friedman, Schinka, Mortimer & Graves, 2002; Hester, Kinsella, Ong & Turner, 2004; Hogervorst, Combrinck, Lapuerta, Rue, Swales, & Budge 2002; Lacritz et al., 2001; Miotto et al., 2012), suggesting older individuals and those with a lower educational levels, perform poorer in the HVLT-R. Other studies have also found race (Norman et al., 2011) and sex (Duff, 2016) to influence performance, however these differences are small and inconsistent.

During the past 15 years, there has been a number of studies which purpose was to obtain normative data for HVLT-R in countries such as the US (Cherner et al., 2007, Duff, 2016, Friedman et al., 2002, Norman et al., 2011), Colombia (Rivera et al., 2015), Argentina, Bolivia, Chile, Cuba, El Salvador, Guatemala, Honduras, Mexico, Paraguay, Peru, Puerto Rico (Arango-Lasprilla et al., 2015e) and Australia (Hester et al., 2004). In general, these studies have been conducted with healthy adult populations, from 18 to 95 years of age and with a minimum education level of 1 year. Most of them have obtained normative data from multiple linear regression models in which sociodemographic variables such as age, sex, and education were included as predictors. The results of these investigations are presented mainly through normative data tables, which allow the conversion of each direct scores into a corresponding percentiles (Arango-Lasprilla et al., 2015e; Cherner et al., 2007; Friedman et al., 2002; Rivera et al., 2015). However, some studies also present their norms in means and standard deviations (Benedict et al., 1998; Hester et al., 2004), and scalar scores (Norman et al., 2011).

Despite the importance of all these studies, there are some limitations. First, in many cases, during the procedure to standardize direct scores, incorrect estimations could be generated, due to an unstandardized distribution of the residuals in the multiple linear regression models; and in some cases, to the segmentation of the groups for the establishment of model predictors (Van Breukelen & Vlaeyen, 2005). Second, none of the studies included participants who are illiterate or uneducated, thus normative data is unavailable for this population, and specially taking into account the influence education has on performance.

Semantic Verbal Fluency (Benton, Hamsher & Sivan, 1994). Verbal fluency has been defined as the ability to form and express words in accordance with required criteria (Wysokiński, Zboralski, Orzechowska, Gałecki, Florkowski, & Talarowska, 2010) and tasks on verbal fluency have been used to assess complex cognitive functioning, including executive dysfunction. There are typically two types of verbal fluency tests, the phonemic condition where subjects must produce words beginning with a specific letter (i.e., letter F, A, or S), and the semantic condition where individuals are required to generate as many words as possible from a given category (i.e., animals) within a limited amount of time (i.e., 60 seconds). They are often examined together, although for this study we focused solely on the semantic component of verbal fluency. The most commonly used categories are animals, fruits and vegetables (Strauss et al., 2006). Other categories that have been used are “things that are in a kitchen”, “things that are in a supermarket” (Heller & Dobbs, 1993), and “verbs or actions” (Piatt, Fields, Paolo & Tröster, 1999; Woods et al. al., 2005b).

As for the psychometric properties of the test, it has been shown to exhibit good internal reliability, with a coefficient of 0.83 (Tombaugh, Kozak, & Rees, 1999) and a good test- retest reliability for both short and long periods of time (weeks or months and 5 years) with coefficients above 0.70 (Harrison, Buxton, Husain, & Wise, 2000; Levine, Miller, Becker, Selnes, & Cohen, 2004; Tombaugh, et al, 1999). Regarding the validity of this test, correlations with other verbal fluency tests (convergent validity) have been calculated, with moderate to high rates (from 0.66 to 0.71; Delis, Kaplan & Kramer, 2001; Riva, Nichelli, & Devoti, 2000).

Some studies have shown verbal fluency test performance to be related to working memory (Fischer-Baum, Miozzo, Laiacona & Capitani, 2016) and verbal intelligence (Miller, 1984). Verbal fluency tests have been used for the evaluation of executive functions (Hankee et al., 2013, Whiteside et al., 2016). However, they have been mainly used for the evaluation of language, both in children (Martins-Oliveira, Mograbi, Gabrig & Charchat-Fichman, 2016; Nieto, Galtier, Barroso & Espinosa, 2008; Prigatano, Gray & Lomay, 2008; Ruffieux et al., 2010; Van der Elst, Hurks, Wassenberg, Meijs & Jolles, 2011), as in healthy adults (Acevedo et al., 2000; Brucki, Malheiros, Okamoto & Bertolucci, 1997, Chavez-Oliveros et al., 2015, Costa et al., 2014, Ferrett et al., 2014). It has also been used for the evaluation of language in patients with Alzheimer's disease (Salvatierra, Rosselli, Acevedo & Duara, 2007), amyotrophic lateral sclerosis (Beeldman et al., 2014), multiple sclerosis (Duque et al., 2012), head injuries (Cralidis & Salley, 2017, Fischer-Baum et al., 2016), mild cognitive impairment (Nutter-Upham et al., 2008), cerebrovascular accidents (Vivas & Naveira, 2010), HIV (Iudicello, Woods, Deutsch &

Grant, 2012; Thames et al., 2012), ADHD (Hurks et al., 2004; Koziol & Stout, 1992), and learning disorders (Hatcher, Snowling & Griffiths, 2002; Reiter, Tucha & Lange, 2005) among others.

Most studies have shown that age, education, and to a lesser extent, sex, can influence performance (Acevedo et al., 2000; Casals-Coll et al., 2013; González, Mungas & Haan, 2005; Kavé, 2005; Olabarrieta-Landa et al., 2015a). Other variables such as the educational level of parents (in the case of children; Van der Elst et al., 2011), presence of depressive symptoms (Acevedo et al., 2000) and IQ (Harrison et al., 2000) have also been found to be predictors of performance in verbal fluency tests.

There are several normative data studies that have been done around the world (e.g., The US [Acevedo et al., 2000; Casals-Coll et al., 2013; Gladsjo et al., 1999], Brazil [Brucki et al., 1997; Machado & Fichman, 2009], México [Chávez-Oliveros et al., 2015; González et al., 2005], Colombia [Olabarrieta-Landa et al., 2015a] among others). Even though most of these studies have been performed in healthy adult populations (Acevedo et al., 2000; Brucki et al., 1997; Buriel, Peña Casanova, Rodés, Gramunt Fombuena & Böhm, 2004; Butman, Allegri, Harris, & Drake, 2000; Casals-Coll et al., 2013; Cavaco et al., 2013; Costa et al., 2014; Gladsjo et al., 1999; Olabarrieta-Landa et al., 2015a), norms have also been developed for healthy children (Beeldman et al., 2014; Ferrett et al., 2014; García, Rodríguez, Martín, Jiménez, Hernández & Díaz, 2012; Gutiérrez et al., 2006, Van der Elst et al., 2006d). In addition, the majority of research conducted with adults has been developed with educated samples, except for a few studies (Brucki et al., 1997; Gladsjo et al., 1999) where samples of people with no education have participated.

Despite the large number of investigations that have aimed to obtain normative data for verbal fluency tests in different populations, and education levels, only two studies (none in Spanish) have provided normative data for people who are illiterate or have no education. This lack of data is, without doubt, a great limitation despite being one of the most frequently used tests by neuropsychologists in Latin America (Arango-Lasprilla et al., 2016; Fonseca-Aguilar et al., 2015).

Procedure

Training and administration procedure of the battery

First, the University of Deusto's (Bilbao, Spain) Ethics Committee approved this study as the coordinating institution. After approval was conceived, any copyrighted test materials (manuals, booklets, and stimulus cards) were purchased directed from the publishers and an invitation was sent to a number of university institutions and research centers from Latin America to participate in the study. In each of the centers and universities, a researcher was appointed to coordinate data collection for the study. The study coordinators performed an online virtual training through the telemedicine platform VSee© and one in-person training in Colombia, Ecuador, and México. During the two-hour long training, the administration and scoring of the tests were reviewed and any doubts were resolved. The coordinator of each institution selected a group of 6–12 graduate students (e.g., master's students), with which the coordinator reviewed the instructions and application and qualification of the tests. Instructional videos were shown during training and given to all institutional coordinators for training purposes. Each video presented the procedure and scoring of all neuropsychological test used in this study.

Data collection began March 2013 and ended June 2017. Recruitment approaches included using word of mouth and door-to-door (for those populations hard to reach in rural areas). Trained students/psychologist met with each participant for approximately 100 minutes to collect sociodemographic/screening information and complete the neuropsychological tests used. It is important to note that the tests used in this dissertation were part of a battery conformed of seven neuropsychological tests, but this dissertation only analyzed four of them. The four selected tests assessed vision and memory (ROCF), executive functioning (M-WCST), verbal learning and memory (HVLT-R) and verbal fluency (semantic verbal fluency). Spanish-language versions of instructions booklets were available for all instruments except for the M-WCST. Spanish administration and an instruction manual for this instrument were created in collaboration with the publishers.

Before starting the battery administration, participants provided informed consent and could withdraw from the study at any time. Since part of the sample in this study was adults who are absolute illiterate, the informed consent was read to them. Methods and procedures were approved through the ethics committees at the University of Deusto in Bilbao, Spain. These tools consisted of: a) a randomized list to determine the order of administration of the test for each participant in order to avoid order bias and cognitive conditioning. To do so, the function $f_x = \mathrm{RANDOM}(\,)$ was used in Microsoft Excel©; b) a template in Microsoft Excel© for entering information to limit bias input information, which was designed using the configuration options *Data validation=custom* (numeric variables), *drop-down lists* (categorical variables), and *configuration formats* to reduce data entry bias: c) examples showing the most frequent errors in the administration and scoring of each test, and e) a virtual folder with a security key for each city, administered by the study coordinator to track data entry.

All the neuropsychological tests were administered according to the specific manual guidelines of each test. Once the database was consolidated, we reviewed the data distribution of frequencies, comparing the values of various statistics and graphs, in order to check for correct processing and characteristics of distributions for each of the variables analyzed. This procedure certified the database was generated correctly and the properties of the observed variables were known. In addition, tools and visual aids were created to achieve standard management process of the battery.

Statistical Analysis

Independent sample t-tests

First, a number of Independent Sample t-test were run to find the difference between our two groups adults who were illiterates (Absolute vs. Functional) and all four neuropsychological tests and the difference between countries (Colombia vs. Other) and all four neuropsychological tests. In order to properly interpret any significant results from the Independent Sample t-test, the Pearson product-moment correlation, using a large size effect ($r \geq 0.50$) as a cutoff point, was used to identify if separate normative data was needed for each category (Colombia Vs. Other, Absolute Vs. Functional illiterate). Anything below the cutoff point of 0.50 ($r \geq 0.10$ small effect; $r \geq 0.30$ medium effect) was not considered robust enough to create separate normative data (Cohen, 1992).

Psychometrics

In order to identify a patient's cognitive disabilities and/or problems, both clinicians and researchers need scientifically accurate instruments. An assessment tool should be scientifically rigorous in terms of two basic psychometric properties: reliability and validity. There are a number of different measures that can be used to validate tests and see how reliable these are.

This dissertation reported reliability in terms of internal consistency, which is how well a test is actually measuring what we want it to measure. On the other hand, validity was reported in terms of construct validity, which is used specifically see whether the test items measured the intended construct.

Reliability

To calculate the psychometric characteristics of reliability, the intraclass correlation coefficient (ICC) as a particular case of generalizability coefficient was estimated (Abad, Díez, Gil & García, 2011). This calculation was carried out in two steps: 1) by obtaining the Cronbach's alpha (α) using the scores of each test (this is the most commonly used method for internal consistency reliability) and 2) by obtaining the ICC using the *consistency* option.

Validity

To estimate construct validity of each neuropsychological tests an exploratory factor analysis (EFA) was run with approximately 50% of the sample and a Confirmatory Factor Analyses (CFA) with the other 50% of the sample. To determine whether a unique factor structure emerged for each of the neuropsychological test, an EFA with principal Component Analysis and a promax rotation was performed on the first 50% of the sample assuming a no priori factor structure. Then, a CFA was performed on the second half specifying the factor structure that emerged from the EFA and omitting items that did not loaded with simple structure in the EFA.

The EFA: This structure was composed of 4 factors or constructs, where each factor was made up from the direct scores of each neuropsychological test. The estimation was made using the maximum likelihood (ML) technique based on structural equation modeling (SEM) using the following expression:

$$X = \Lambda_x \xi + \varepsilon,$$

where X represents the matrix of observed variables, Λ_x refers to the matrix of the factor loads, ξ the values of the latent factors and ε the residual derived from the statistical model. To evaluate the goodness of fit of the proposed factor model, the usual values of global adjustment and the values of each factor loads were used (Guàrdia & Benítez, 2012).

Normative Procedure

For each of the multiple linear regression models, the following assumptions were evaluated: a) collinearity through the values of Variance Inflation Factors (VIFs) which should not be greater than 10, and the tolerance values of collinearity, which should not exceed the value one (Kutner, Nachtsheim, Neter & Li, 2005); b) homoscedasticity, which was evaluated by grouping the participants in quartiles of the predictive scores and applying the Levene test to residual scores (homoscedasticity was rejected when $p > 0.005$); c) normal distribution of the residuals by conducting a Kolmogorov–Smirnov (K-S) test; d) the existence of influential values by calculating Cook's distance. The Cook distance was evaluated using the 0.50 as the cut-off point. A value is considered to be influential in the model when the resulting value exceeds 0.50 or more (Kutner et al., 2005).

The methodology to generate normative data based on multiple linear regressions allowed us to calculate normative data using the four-step procedure described by Van Breukelen et al., (2005): 1) Calculation of predictive scores using multiple linear regression models. The regression model assumed that $\boldsymbol{Y}_i = \boldsymbol{X}_i\boldsymbol{\beta} + \boldsymbol{\varepsilon}_i$, where $\boldsymbol{Y}_i$ was the vector of the measurements, $\boldsymbol{X}_i$ the design matrix for the fixed effects, $\boldsymbol{\beta}$ the vector of the regression coefficients (fixed effects), and $\boldsymbol{\varepsilon}_i$ the vector of the residual components. Each multiple linear regression allows the creation of a final model with the predictive variables that affect each of the scores of the neuropsychological tests studied. For this, a multiple linear regression model was created from the direct score of each of the tests. The full model included age, age^2, and sex as predictive variables. Age as a continuous variable was centralized (=Age- average age of the sample) and then, age^2 was calculated to avoid multicollinearity (Aiken, West & Reno, 1991). If any predictive variable was not statistically significant ($p > 0.005$) the multiple linear regression analysis was repeated eliminating said variable from the equation. The cutoff point was $p > 0.005$ (p-value =0.05/3 predictor variables ≈ 0.005) to avoid Type I errors (Van der Elst, Van Boxtel, Van Breukelen & Jolles, 2006). The sex variable was coded as 1 =male and 0 =female. For the calculation of the predictive core, the final multiple linear regression model that was previously estimated was used and replaced with a formula $\hat{y}_i = b_0 + b_1 \cdot (Age - 60.9)_i + b_2 \cdot (Age - 60.9)^2{}_i + b_3 \cdot\ Sex_i$.

2) To obtain the residual value (e_i), a subtraction was made between the raw score of a neuropsychological test (y_ii) and the predictive value previously calculated ($\hat{y}_i$). As shown in the following formula: $\hat{e}_i = Y_i - \hat{Y}_i$. 3) Using the residual standard deviation (SD_e) value provided by the multiple linear regression model, residual values were standardized. To do this, it was necessary to divide the residual value (e_i) between the residual standard deviation (SD_e) obtained in the regression model: $\hat{z}_i = \hat{e}_i\ /SD_e$. When heteroscedasticity occurred, the *SD* (residual) values was estimated for each quartile of predictive scores to account for the lack of homoscedasticity in a model and to have a greater precision in the generation of normative data. 4) Finally, the standardized residuals (z_i) were converted into percentiles through the standard normal cumulative distribution function (if the assumed normality model of the residuals was met) or through the empirical cumulative distribution function of the residuals standardized (if

standardized residuals were not normally distributed). All analyses were performed using SPSS version 24 (IBM Corp., 2016) and the SEM library for R (Fox et al., 2017).

Results

Independent samples t-test

Twenty independent-samples t-tests were conducted to compare all four neuropsychological tests by type of illiteracy (Absolute vs. Functional) and country (Colombia vs. Other). There was a significant difference in the scores by type of illiteracy for all neuropsychological tests. However, in order to properly interpret these significant results, the Pearson product-moment correlation was used using Cohen's size effect guidelines ($r \geq 0.10$ small effect; $r \geq 0.30$ medium effect; $r \geq 0.50$ large effect; Cohen, 1992). Using a large effect size as our cut off, any values below 0.50 were not considered robust enough for the development of separate normative data by group ("Colombia Vs. Other" and "Absolute illiterate Vs. Functional illiterate; see table 2b). In addition, there was a significant difference in the scores by country for the M-WCST (number of correct categories, number of total errors, and number perseveration errors) and the HVLT-R (number of recognitions). Nevertheless, Cohen's effect size cut points suggest a low practical significance (small effect size) thus normative data was not divided by country (see table 2c).

Table 2b. Independent sample t-test and effect sizes by type of illiteracy

Neuropsychological Test	Type of illiteracy	Mean	*SD*	t	df	Sig. (2-tailed)	Effect size
ROCF Copy	Absolute	16.256	9.488	-6.448	297	<.001	0.35
	Functional	23.241	9.169				
ROCF Memory	Absolute	7.398	6.591	-5.198	251	<.001	0.311
	Functional	11.734	7.407				
M-WCST # of correct categories	Absolute	2.017	1.564	-5.525	303	<.001	0.302
	Functional	3.0248	1.893				
M-WCST # total errors	Absolute	13.058	10.408	3.299	383	<.001	0.166
	Functional	9.67	9.238				
M-WCST # perseveration errors	Absolute	25.308	9.82	5.085	301	<.001	0.28
	Functional	19.465	11.965				
Semantic Verbal Fluency: Animals	Absolute	10.942	3.761	-3.622	283	<.001	0.21
	Functional	12.621	4.954				
Semantic Verbal Fluency: Fruits	Absolute	9.486	3.288	-3.534	306	<.001	0.198
	Functional	10.819	3.906				
HVLT-R total recall	Absolute	14.139	4.392	-3.576	389	<.001	0.178
	Functional	15.819	4.82				
HVLT-R delayed recall	Absolute	3.965	2.232	-3.175	308	0.002	0.177
	Functional	4.77	2.617				
HVLT-R recognition	Absolute	9.856	1.982	-3.33	379	<.001	0.168
	Functional	10.465	1.624				

Table 2c. Independent Sample t-test and Effect Sizes by Country

Neuropsychological test	Country	Mean	*SD*	*t*	df	Sig. (2-tailed)	Effect size
ROCF Copy	Colombia	17.645	9.518	1.005	388	0.316	-0.197
	Other	18.649	10.0045				
ROCF Memory	Colombia	8.404	6.4328	-1.735	388	0.084	-0.088
	Other	9.629	7.2877				
M-WCST # of correct categories	Colombia	2.133	1.4784	-2.889	394	0.004	-0.147
	Other	2.646	1.9371				
M-WCST # perseveration errors	Colombia	25.434	9.6601	3.949	394	<.001	0.198
	Other	21.094	11.6833				
M-WCST # total errors	Colombia	13.376	10.4477	3.149	394	0.002	0.156
	Other	10.229	9.386				
Semantic Verbal Fluency: Animals	Colombia	11.69	4.2421	0.413	398	0.68	0.02
	Other	11.509	4.4113				
Semantic Verbal Fluency: Fruits	Colombia	10.207	3.7452	1.077	398	0.282	0.054
	Other	9.814	3.51				
HVLT-R total recall	Colombia	14.736	4.4305	-0.377	400	0.706	-0.019
	Other	14.912	4.8147				
HVLT-R delayed recall	Colombia	9.816	1.8058	0.625	399	0.532	0.032
	Other	9.665	2.764				
HVLT-R recognition	Colombia	2.138	1.6069	-3.834	400	<.001	-0.196
	Other	3.123	3.0837				

Psychometrics

Reliability. Reliability was calculated by estimating the coefficient of Cronbach's alpha (α) and the intraclass correlation coefficient (*ICC)* with a confidence interval of 95%, as shown in table 2d. In general, an adequate to good reliability was observed on the scores of the tests studied, where the values of the coefficients are similar and with acceptable confidence intervals.

It has been recognized that two-item tests are problematic when measuring reliability. Many researchers use Cronbach's alpha for measuring two-item test reliability, but other researchers suggest that the Spearman-Brown coefficient can be used to correct for this type of measure design (Eisinga, Grotenhuis, & Pelzer, 2013; Shrout, 1998). The Spearman-Brown coefficient is always higher than Cronbach's alpha, and is consequently a more suitable way to measure reliability for two-item tests (Eisinga et al., 2013)

Table 2d. Reliability Coefficients for Each Neuropsychological Test

Test	# Items	α/Spearman-Brown correlation	ICC (CI 95%) Average measures
ROCF	2	0.838/.866**	.866† (.795 - .863)
M-WCST*	2	0.847/.850**	.850† (.818 - .878)
Verbal Fluency	3	0.788	.788† (.749 - .821)
HVLT-R	4	0.697	.697† (.646 - .743)

†This estimate is calculated assuming that the effect of the interaction is absent, otherwise it is not estimable
*The Cronbach Alpha of the M-WCST improved from 0.525 to 0.851 after deleting one item
** Spearman-Brown correlation reported for two-item test

Construct Validity. An EFA was estimated with approximately 50% of the sample (n=197) extracted randomly from the original sample. This process was intended to identify a factorial structure without any restriction. The relationship between factors was assumed, the factorial loads were estimated after a Promax rotation, and those factors that showed an eigenvalue greater than 1 were maintained (Guttman, 1954). This criterion identified four factors that accounted for a total of 79.241% of the initial variance. Test scores of this study are grouped in such a way that the EFA model is confirmed (See table 2e).

It is observed that each factor groups the scores corresponding to each neuropsychological test. The first factor groups the test scores of the HVLT-R, the second factor groups the test scores of M-WCST (categories, total errors and perseverations), the third factor groups the scores of the verbal semantic fluency (Animals, Fruits and Professions), and the last factor groups the scores of the ROCF (Copy and Memory). It is evident that there is adequate construct validity in global terms, which was the object of this specific analysis.

To assess the goodness-of-fit, a CFA was administered to approximately 50% of the remaining random sample (n=191) in order to assess the factor structure resulting from the EFA. To evaluate the CFA, the general adjustment values and the values of each factorial load were used. The general adjustment values that were obtained were the following: χ^2 =110.14; (df=48; *p*=8.671); CFI (Comparative Fit Index) =0.93; GFI (Goodnes of Fit Index) =0.90; AGFI (Adjusted Goodnes of Fit Index) =0.84; BBNFI (Bentler Bonnet Normed Fit Index) =0.93; RMSEA (Root Mean Square Error of Approximation) =0.085. As a result, the indices obtained from the CFA showed that the factor structure proposed gives construct validity to the neuropsychological tests used in this study are adequate (Bentler & Dudgeon, 1996; Schreiber, Nora, Stage, Barlow & King, 2006).

Table 2e. Factor loadings EFA and CFA

	Factors				CFA
	1	2	3	4	Estimation
HVLT-R Total	**0.999**	0	-0.001	0.019	0.721
HVLT-R trail 1	**0.641**	-0.053	-0.021	0.164	0.993
HVLT-R trail 2	**0.871**	-0.081	0.051	-0.056	1.458
HVLT-R trail 3	**0.906**	0.111	-0.029	-0.045	1.469
M-WCST Total errors	0.006	**0.976**	-0.018	0.056	11.321
M-WCST Perseverations	0.067	**0.911**	0.031	0.087	7.45
M-WCST correct categories	0.11	**-698**	-0.004	0.165	-1.144
Animals	-0.056	0.065	**0.935**	-0.04	3.321
Professions	-0.114	-0.101	**0.804**	0.167	2.643
Fruits	0.203	0.036	**0.773**	-0.111	2.398
ROCF Copy	-0.003	0.036	0.019	**0.955**	7.782
ROCF Memory	0.061	0.012	-0.025	**0.909**	5.873

As shown in the table above, the values of the CFA are high in all cases (λ_i> 0.721), and with adequate signs according to each score. The normalized residuals, both the median (<0.001) and the mean (0.315), indicate that the residuals are close to zero. The coefficients of determination (R^2) of each of the observed variables (R-square Endogenous Variables) are quite high (0.1281 - 1.1308), which indicates an evident equivalence between the observable variables and their association with the proposed factors ξ_x.

<u>Assumptions</u>

The normative data were generated from the final multiple linear regression models for each score. For each final model, the assumptions of multicollinearity, homoscedasticity, normality and influential values were checked. The results of the verification of these assumptions for each test can be seen in Table 2f.

Table 2f. Assumptions of multicollinearity, homoscedasticity, normality and influential values for the final multiple linear regression models

Test	Multicollinearity		Homocedasticity	Normality	Influential values
	Tolerance	VIF	Levene Test	K-S	Max Cook's Distances
ROCF Memory	1	1	9.044 (p<0.001)	0.100 (p<0.001)	0.08
ROCF Copy	0.998	1.002	3.211 (p=0.023)	0.069 (p<0.001)	0.021
M-WCST Correct categories	1	1	4.662 (p<0.001)	0.138 (p<0.001)	0.019
M-WCST Total errors	1	1	1.676 (p=0.172)	0.054 (p=0.009)	0.028
M-WCST Perseveration	--	--	--	--	--
Animals	0.81	1.234	1.285 (p=0.944)	0.040 (p=0.170)	0.068
Fruits	0.81	1.234	1.564 (p=0.198)	0.025 (p=0.200)	0.064
Professions	1	1	3.995 (p=0.008)	0.070 (p<0.001)	0.062
HVLT-R Total	0.812	1.232	2.229 (p=0.084)	0.038 (p=0.200)	0.03
HVLT-R Delayed Recall	1	1	2.280 (p=0.079)	0.125 (p<0.001)	0.045
HVLT-R Recognition	1	1	1.335 (p=0.263)	0.068 (p<0.001)	0.042

Regarding the multicollinearity assumption, no evidence of multicollinearity was found among the predictive variables of the final models, where all the maximum FIV values were lower than 1.234, not exceeding the suggested cut-off point (VIF <10). The tolerance values did not exceed one (1). On the other hand, the homoscedasticity evaluation of each of the final models was done out through the Levene statistic. As a result, the ROCF Memory (Levene=9.044), and M-WCST Correct categories (Levene=4.4662) showed heterogeneity. In these cases, a residual standard deviation (SD_e) was estimated in each of the predictive scores quartiles in order to compensate for the lack of homoscedasticity in the model and to have greater precision in the generation of normative data. For the other test scores, the Levene statistic showed homoscedasticity and no other procedure was necessary.

The evaluation of the normality of the standardized residual values of each final model showed that a normal distribution function could be used for the transformation of z_i to percentile in all neuropsychological test scores, except for the ROCF Memory (K-S=0.100), ROCF Copy (K-S=0.069), M-WCST Correct Categories (K-S = 0.138), Professions (K-S=0.070), HVLT-R Delayed Recall (K-S=0.125) and HVLT-R Recognition (K-S= 0.068), which did not present normality of the standardized residuals. For this last case of non-normality, an empirical distribution function was used for the transformation of z_i to percentile. Finally, influential values were not found in the final models, where the Maximum Cook's Distance value was 0.068 (Animals), no values exceeded 0.50 thus it was not necessary to exclude data from the final models.

Final Multiple Linear Regression Models

Final Multiple Linear Regression Model for the ROCF

Rey–Osterrieth Complex Figure (ROCF). To determine the effect of the sociodemographic variables on the ROCF Copy and ROCF Memory scores, two multiple linear regression models were performed. The independent variables for both models were age, age^2, and sex, while the dependent variables were the total score of the Copy and Memory of the

ROCF. To generate normative data, the final model of multiple linear regression model and residual standard deviations was used.

Table 3a shows the results of the two final multiple linear regression models for the ROCF (Copy and Memory). The final multiple linear regression model for the ROCF Copy was significant (p <0.001) and explained 7.3% of the variance of this score. The variables age and sex had a significant effect on the score of the ROCF Copy, where older men had higher scores than older women. Showing a slower linear decline in men than in women, as they get older (Figure 3a). The variables age^2 was not significant.

The final multiple linear regression model for the ROCF Memory was significant (p <0.001) and explained 7.3% of the variance of this score. It was found that the variable age had a significant effect on the ROCF Memory score, where the older a participant is the lower the score, showing a linear decline in the scores according to age (Figure 3b). The variables sex and age^2 were not significant.

Table. 3a Final multiple linear regression models for the ROCF scores

Test		**B**	**Std. Error**	***T***	***Sig.***	***R^2***	***SDe* (residual)**
ROCF Memory	(Constant	9.069	0.345	26.286	<0.001	0.073	6.708
	Age-60.9	-0.101	0.019	-5.428	<0.001		
ROCF Copy	(Constant	17.231	0.634	27.175	<0.001	0.073	9.442
	Age-60.9	-0.135	0.026	-0.084	<0.001		
	Sex	1.95	0.987	3.892	0.049		

Figure 3a. Predictive scores for the ROCF Copy

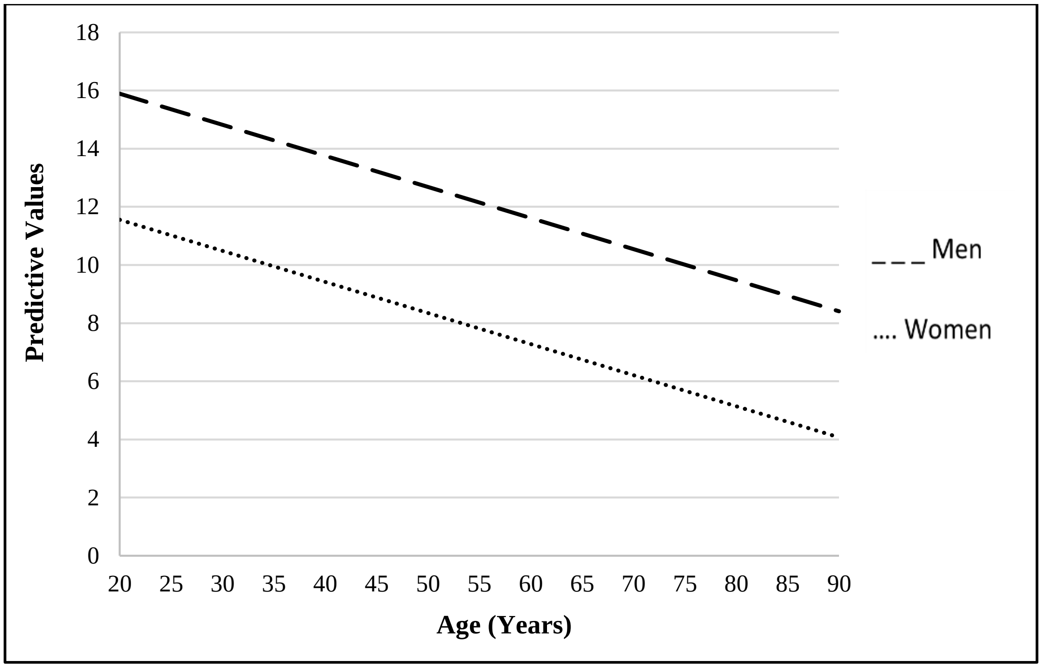
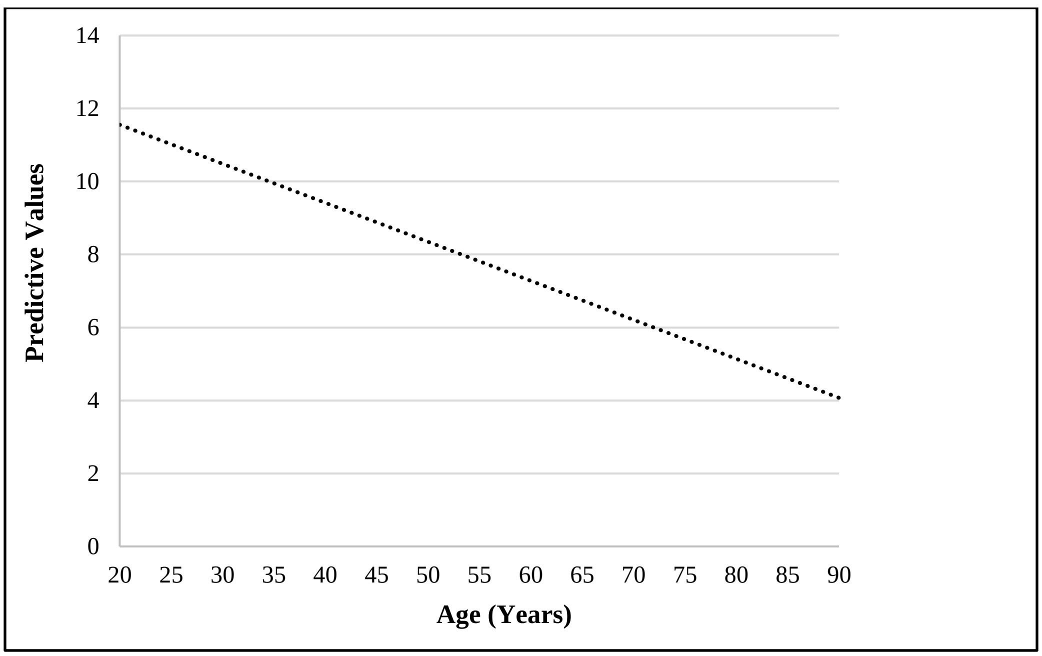


Figure 3b. Predictive scores for the ROCF Memory



On regards to the verification of the statistical assumptions for the multiple linear regression models, the model for the ROCF Copy did not yield a normal distribution (K-

S=0.069; p<0.001) but did show homoscedasticity of the residual values (Levene=3.211; p=0.023), therefore, it was necessary to estimate the standard deviation residual for each of the ranges of the predictive values as shown in Table 3b. The final multiple linear regression model of the ROCF Memory did not show a normal distribution (K-S=0.100; p<0.001) or homoscedasticity (Levene=9.044; p<.001) of the residual values, therefore, it was necessary to create an accumulated empirical distribution of the standardized z-values, and estimate the standard deviation residual for each of the ranges of the predictive values as shown in Table 3b. Both models showed absence of multicollinearity, given that the FIV values were lower than 10 (FIV $\leq$ 1.002) and the collinearity tolerance values did not exceed the value of 1. The final models did not show influential cases (the maximum distance value of Cook was 0.021).

Table. 3b Standard Deviation Residuals for the ROCF

	Predictive Value $(\hat{Y}_i)$	**Standard Deviation Residual** SD_e
Copy	≤16.000	8.917
	16.001-17.487	8.778
	17.488-19.963	10.673
	≥19.964	9.150
Memory	≤7.545	5.392
	7.546-8.806	5.911
	8.807-10.371	8.121
	≥10.372	7.078

Normative data for the ROCF

Normative data of the ROCF Copy and ROCF Memory were obtained using the four-step procedure explained in the *normative procedure* of the method section. In order to facilitate the compression of the procedure, an example will be provided. Suppose you want to know the percentile of a 47-year-old man, and who obtained a score of 8 in the ROCF Memory. To obtain the percentile, the following steps should be followed:

1. Calculate the predictive value for the ROCF Memory using the following formula: $\hat{Y}_i = b_0 + b_1 \bullet (Age - 60.9)_i$. Using table 3a we can obtain the beta values that are part of this formula. The beta values of the variables age must be replaced into the formula. The formula would be as follows: $\hat{Y}_i = 17.231 + [-0.135 \bullet (Age - 60.9)_i]$

   $\hat{Y}_i = 9.069 + [-0.101 \bullet (47 - 60.9)]$ = 9.069 + [-0.101 (-13.9)]

   $\hat{Y}_i = 10.472$

2. Calculate the residual value e_i. To do this, a subtraction must be made between the direct score of the ROCF Memory that the participant has obtained (Y_i) and the predictive value ($\hat{Y}_i$) as shown below:

   $e_i = Y_i - \hat{Y}_i$

   $e_i = 8 - 10.472$ = -2.472

3. Transform the residual value into z_i scores. For this purpose, it is necessary to consult the column SD_e of Table 2h and take the specific value of the ROCF Memory which is 7.078 with the residual value, we proceed to transform the residual value to score z_i using the following equation: $z_i = e_i / SD_e$

   $z_i = -2.472/7.078$ = -0.349

4. Convert the z_i score to its corresponding percentile using the values of the z_i column found in Table 3c. A z_i score of -0.329 correspond to the 45th percentile.

Table 3c. Corresponding Percentiles to the z_i Values of the ROCF Memory

z_i	Per.	z_i	Per.	z_i	Per.	z_i	Per.
≤-1.4523	1	-0.7645	26	-0.1826	51	0.5698	76
-1.3111	2	-0.7344	27	-0.1546	52	0.6481	77
-1.2743	3	-0.7016	28	-0.131	53	0.705	78
-1.2561	4	-0.6935	29	-0.0993	54	0.7536	79
-1.2326	5	-0.6764	30	-0.0732	55	0.8711	80
-1.2014	6	-0.6666	31	-0.0389	56	0.9449	81
-1.1929	7	-0.6354	32	-0.0103	57	0.9714	82
-1.1521	8	-0.6228	33	0.027	58	1.0106	83
-1.1277	9	-0.617	34	0.0717	59	1.0568	84
-1.1035	10	-0.6022	35	0.1051	60	1.0884	85
-1.0844	11	-0.6004	36	0.1328	61	1.1677	86
-1.0497	12	-0.5858	37	0.1695	62	1.2415	87
-1.0294	13	-0.5612	38	0.2421	63	1.3294	88
-1.0144	14	-0.5359	39	0.2821	64	1.4744	89
-0.9912	15	-0.5201	40	0.3128	65	1.6101	90
-0.9722	16	-0.4751	41	0.3386	66	1.7318	91
-0.9496	17	-0.4468	42	0.3628	67	1.7797	92
-0.9308	18	-0.3976	43	0.3979	68	1.8293	93
-0.9054	19	-0.3539	44	0.4082	69	1.9064	94
-0.8843	20	-0.3288	45	0.4232	70	2.0888	95
-0.8722	21	-0.3063	46	0.4395	71	2.2086	96
-0.8594	22	-0.2678	47	0.4732	72	2.5429	97
-0.8331	23	-0.2546	48	0.5056	73	2.9105	98
-0.8088	24	-0.2291	49	0.5181	74	0.5698	99
-0.7861	25	-0.2084	50	0.5499	75	≥0.5699	100

Use of Normative Data Tables for the ROCF

The procedure described above is time-consuming and increases the likelihood of human error. With the objective to reduce these disadvantages, normative data for the ROCF is presented in table form with approximate percentiles (Table 3d & Table 3e). For the development of these tables, the four-step procedure described in the methodology of this dissertation was used. Going back to our example but now using Table 3d to help us obtain the approximate percentile of a 47-year-old person who obtained a score of 8 in the ROCF Memory, we have to first look at the age column "43-47" years. Then, find the direct score obtained by the person (8), following by the percentile corresponding to that specific score. For this example, we will look for the most approximate score to our direct score (8), which is 9.268 and corresponds to the 50th percentile.

Table 3d. Normative Data for the ROCF Memory Stratified by Age

z	Percentile	Age (Years)											
		18-22	23-27	28-32	33-37	38-42	43-47	48-52	53-57	58-62	63-67	68-72	>73
1.906	**95**	25.979	25.474	24.969	24.464	23.959	23.454	22.949	22.444	21.939	21.434	20.929	20.424
1.474	**90**	23.0812	22.5762	22.0712	21.5662	21.0612	20.5562	20.0512	19.5462	19.0412	18.5362	18.0312	17.5262
1.057	**85**	20.2799	19.7749	19.2699	18.7649	18.2599	17.7549	17.2499	16.7449	16.2399	15.7349	15.2299	14.7249
0.754	**80**	18.246	17.741	17.236	16.731	16.226	15.721	15.216	14.711	14.206	13.701	13.196	12.691
0.423	**70**	16.0297	15.5247	15.0197	14.5147	14.0097	13.5047	12.9997	12.4947	11.9897	11.4847	10.9797	10.4747
0.105	**60**	13.8959	13.3909	12.8859	12.3809	11.8759	11.3709	10.8659	10.3609	9.8559	9.3509	8.8459	8.3409
-0.208	**50**	11.793	11.288	10.783	10.278	9.773	9.268	8.763	8.258	7.753	7.248	6.743	6.238
-0.52	**40**	9.7021	9.1971	8.6921	8.1871	7.6821	7.1771	6.6721	6.1671	5.6621	5.1571	4.6521	4.1471
-0.676	**30**	8.6536	8.1486	7.6436	7.1386	6.6336	6.1286	5.6236	5.1186	4.6136	4.1086	3.6036	3.0986
-0.884	**20**	7.259	6.754	6.249	5.744	5.239	4.734	4.229	3.724	3.219	2.714	2.209	1.704
-0.991	**15**	6.5419	6.0369	5.5319	5.0269	4.5219	4.0169	3.5119	3.0069	2.5019	1.9969	1.4919	--
-1.104	**10**	5.7886	5.2836	4.7786	4.2736	3.7686	3.2636	2.7586	2.2536	1.7486	1.2436	--	--
-1.233	**5**	4.9226	4.4176	3.9126	3.4076	2.9026	2.3976	1.8926	1.3876	--	--	--	--

Table 3e. Normative Data for the ROCF Copy by Age and Sex

	Per.	Age (Years)											
		18-22	23-27	28-32	33-37	38-42	43-47	48-52	53-57	58-62	63-67	68-72	73-77
Men	95	--	--	--	--	---	--	35.825	35.15	34.475	33.8	33.125	32.45
	90	--	--	--	35.863	35.188	34.513	33.838	33.163	32.488	31.813	31.138	30.463
	85	35.905	35.23	34.555	33.88	33.205	32.53	31.855	31.18	30.505	29.83	29.155	28.48
	80	34.69	34.015	33.34	32.665	31.99	31.315	30.64	29.965	29.29	28.615	27.94	27.265
	70	31.057	30.382	29.707	29.032	28.357	27.682	27.007	26.332	25.657	24.982	24.307	23.632
	60	27.19	26.515	25.84	25.165	24.49	23.815	23.14	22.465	21.79	21.115	20.44	19.765
	50	24.44	23.765	23.09	22.415	21.74	21.065	20.39	19.715	19.04	18.365	17.69	17.015
	40	21.607	20.932	20.257	19.582	18.907	18.232	17.557	16.882	16.207	15.532	14.857	14.182
	30	18.003	17.328	16.653	15.978	15.303	14.628	13.953	13.278	12.603	11.928	11.253	10.578
	20	15.225	14.55	13.875	13.2	12.525	11.85	11.175	10.5	9.825	9.15	8.475	7.8
	15	13.913	13.238	12.563	11.888	11.213	10.538	9.863	9.188	8.513	7.838	7.163	6.488
	10	12.269	11.594	10.919	10.244	9.569	8.894	8.219	7.544	6.869	6.194	5.519	4.844
	5	10.709	10.034	9.359	8.684	8.009	7.334	6.659	5.984	5.309	4.634	3.959	3.284
Women	95	--	--	--	35.9	35.225	34.55	33.875	33.2	32.525	31.85	31.175	30.5
	90	35.938	35.263	34.588	33.913	33.238	32.563	31.888	31.213	30.538	29.863	29.188	28.513
	85	33.955	33.28	32.605	31.93	31.255	30.58	29.905	29.23	28.555	27.88	27.205	26.53
	80	32.74	32.065	31.39	30.715	30.04	29.365	28.69	28.015	27.34	26.665	25.99	25.315
	70	29.107	28.432	27.757	27.082	26.407	25.732	25.057	24.382	23.707	23.032	22.357	21.682
	60	25.24	24.565	23.89	23.215	22.54	21.865	21.19	20.515	19.84	19.165	18.49	17.815
	50	22.49	21.815	21.14	20.465	19.79	19.115	18.44	17.765	17.09	16.415	15.74	15.065
	40	19.657	18.982	18.307	17.632	16.957	16.282	15.607	14.932	14.257	13.582	12.907	12.232
	30	16.053	15.378	14.703	14.028	13.353	12.678	12.003	11.328	10.653	9.978	9.303	8.628
	20	13.275	12.6	11.925	11.25	10.575	9.9	9.225	8.55	7.875	7.2	6.525	5.85
	15	11.963	11.288	10.613	9.938	9.263	8.588	7.913	7.238	6.563	5.888	5.213	4.538
	10	10.319	9.644	8.969	8.294	7.619	6.944	6.269	5.594	4.919	4.244	3.569	2.894

Final Multiple Linear Regression Models for the M-WCST

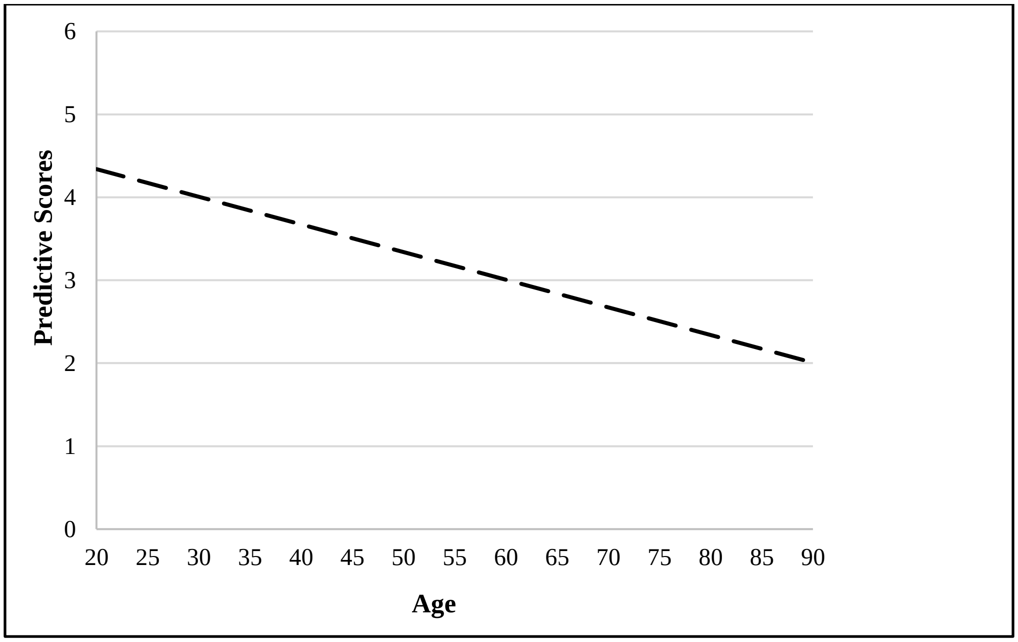
The Modified Wisconsin Card Sorting Tests (M-WCST). To determine the effects of the sociodemographic variables on the M-WCST scores (correct categories, perseverative errors and total errors), three multiple linear regression models were performed. The independent variables for the three models were age, age2, and sex while the dependent variables were each of the test scores (correct categories, perseverative errors and total errors). To generate normative data we used the final multiple linear regression model and the standard deviation of the residual values of each model. For each final multiple linear regression model, the assumptions of multicollinearity, normality, homoscedasticity and the existence of influential values were evaluated.

Table 4a shows the results of the three final multiple linear regression models of correct categories, and total errors. The final multiple linear regression model for correct categories was significant (p <0.001) and explained 3.4% of the variance of this score. The variables age had a significant effect on the correct categories score, a linear decline in the scores can be seen according to age, with lower scores as people get older (Figure 4a). The variables age2 and sex were not significant.

Table. 4a Final multiple Linear Regression Models for the M-WCST Scores

Test		**B**	**Std. Error**	***T***	***Sig.***	R^2	***SDe* (residual)**
M-WCST Correct Categories	(Constant)	2.414	0.089	27.159	<0.001	0.034	1.737
	Age-60.92	-0.017	0.005	-3.664	<0.001		
M-WCST Total Error	(Constant)	22.958	0.561	40.957	<0.001	0.015	10.955
	Age-60.92	0.072	0.03	2.374	0.018		

Figure 4a. Predictive scores for the M-WCST Correct categories



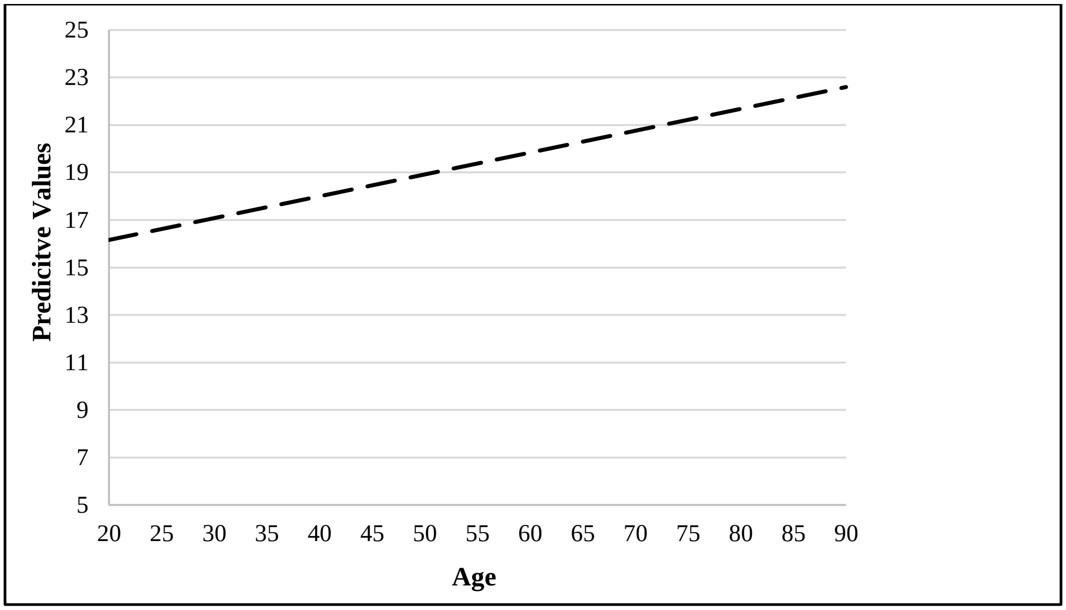
The final multiple linear regressions model for perseverative errors was not significant (p=0.521). The final multiple linear regression model for total errors was significant (p =0.018) and explained 1.5% of the variance of this score. The age variables had a significant effect on the total errors score, where the scores increased linearly according to age, meaning the older an individual the more total errors (Figure 4b). The variables age2 and sex were not significant.

Table 4b. Standard Deviation Residuals for the M-WCST

	Predictive Value	**Standard Deviation Residual**
M-WCST Correct categories	≤2.150	1.536
	2.151-2.368	1.604
	2.369-2.638	1.851
	≥2.639	1.903

M-WCST Total errors	For any value	10.94

Figure 4b. Predictive Scores of the M-WCST Total Errors



In the confirmation of the statistical assumptions for the final multiple linear regression models, the final model of the M-WCST Correct categories did not show a normal distribution (K-S=0.138; p<0.001) or homoscedasticity (Levene=4.662; p<0.001) of the residual values, therefore, it was necessary to create an accumulated empirical distribution of the standardized z-values, and estimate the standard deviation residual for each of the ranges of the predictive values as shown in Table 4b. The model on M-WCST Total errors (K-S=0.054, p=0.009) showed a normal distribution and homoscedasticity of residual values (Levene=1.676; p=0.172). The two models did not present multicollinearity (FIV values were less than 10, FIV ≤ 1.000, collinearity tolerance values did not exceed the value of 1) and there were no influential cases (Cook's maximum distance value was 0.028).

Normative data for the M-WCST

Normative data of the M-WCST Correct categories and M-WCST Total error were obtained using the four-step procedure explained in the *normative procedure* of the method section. In order to facilitate its compression, an example will be provided. Suppose you want to know the percentile of a 35-year-old man, who obtained a Total error score of 16 in the M-WCST. To obtain the percentile, the following steps should be followed:

1. Calculate the predictive value for correct categories using the following formula: $\hat{Y}_i = b_0 + b_1 \bullet (Age - 60{,}9)_i$ Using Table 4a we can obtain the beta values that are part of this formula. The beta values of the variables age must be replaced into the formula. The formula would be as follows: $\hat{Y}_i = 22.958 + [0.072 \bullet (Age - 60.9)_i]$

   $\hat{Y}_i = 22.958 + [0.072 \bullet (35 - 60.9)]$ = 22.958 + [0.072(-25.9)]

   $\hat{Y}_i = 21.093$

2. Calculate the residual value. To do this, a subtraction must be made between the direct score of the total error the participant has had (Y_i) and the predictive value ($\hat{Y}_i$) as shown below:

   $e_i = Y_i - \hat{Y}_i$

   $e_i = 16 - 21.093$ = $e_i = 5.093$

3. Transform residual value into z_i score. For this purpose, we must select the Colum SD_e in Table 4b to select the value specific to M-WCST Total errors, which is of 10.940. With this value, we proceed to transform the residual value to score $z_i$using the following equation:

   $z_i = e_i / DE_e$

   $z_i = 5.093 / 10.940$ = $z_i = 0.465$

4. Convert the z_i score to its corresponding percentile. In the case of the M-WCST Total error, the standardized residual values have a normal distribution, so any of the following tools must be can be used to find the percentile: 1) normal cumulative distribution tables (Strauss et al., 2006) or 2) online calculators (e.g., http: //www.measuringu.com/pcalcz/). In this example, the percentile for the value of z_i=0.465 using an online calculator is 69.90.

Use of Normative Data Tables for the M-WCST

Normative data for the M-WCST will be presented in tables with approximate percentiles (Table 4c and Table 4d). For the generation of these tables, the four-step procedure described in the methodology was used. Continuing with the previous example, using Table 4c to obtain the approximate percentile of a 35-year-old individual who obtained a total error score of 16 in the M-WCST total errors, we have to first look for the participant's age (35 years) that is in the column ranging between "33-37" years, and then down the column to find the closet direct score to our participant (16). For this example, a person that is 35 years of age with 16 total errors is equivalent to having a percentile of 70.

Table 4c. Normative data for the M-WCST Total Errors by Age

z	Percentile	Age (Years)											
		18-22	23-27	28-32	33-37	38-42	43-47	48-52	53-57	58-62	63-67	68-72	>73
1.580	**95**	--	0.083	0.443	0.803	1.163	1.523	1.883	2.243	2.603	2.963	3.323	3.683
1.212	**90**	2.482	2.842	3.202	3.562	3.922	4.282	4.642	5.002	5.362	5.722	6.082	6.442
1.027	**85**	7.202	7.562	7.922	8.282	8.642	9.002	9.362	9.722	10.082	10.442	10.802	11.162
0.903	**80**	9.961	10.321	10.681	11.041	11.401	11.761	12.121	12.481	12.841	13.201	13.561	13.921
0.590	**70**	15.108	15.468	15.828	16.188	16.548	16.908	17.268	17.628	17.988	18.348	18.708	19.068
0.368	**60**	18.644	19.004	19.364	19.724	20.084	20.444	20.804	21.164	21.524	21.884	22.244	22.604
0.111	**50**	21.229	21.589	21.949	22.309	22.669	23.029	23.389	23.749	24.109	24.469	24.829	25.189
-0.125	**40**	24.043	24.403	24.763	25.123	25.483	25.843	26.203	26.563	26.923	27.283	27.643	28.003
-0.448	**30**	26.474	26.834	27.194	27.554	27.914	28.274	28.634	28.994	29.354	29.714	30.074	30.434
-0.918	**20**	29.901	30.261	30.621	30.981	31.341	31.701	32.061	32.421	32.781	33.141	33.501	33.861
-1.170	**15**	31.259	31.619	31.979	32.339	32.699	33.059	33.419	33.779	34.139	34.499	34.859	35.219
-1.601	**10**	33.285	33.645	34.005	34.365	34.725	35.085	35.445	35.805	36.165	36.525	36.885	37.245
-1.853	**5**	37.314	37.674	38.034	38.394	38.754	39.114	39.474	39.834	40.194	40.554	40.914	41.274

Table 4d. Normative Data for the M-WCST Total Categories Stratified by Age

Direct score	**Age (Years)**												
	18-22	**23-27**	**28-32**	**33-37**	**38-42**	**43-47**	**48-52**	**53-57**	**58-62**	**63-67**	**68-72**	**73-77**	**>77**
6	78	79	80	83	84	86	87	89	90	91	92	97	97
5	69	70	72	74	76	78	78	79	80	83	84	90	91
4	50	54	59	64	67	68	69	70	72	74	76	78	80
3	28	34	40	42	44	47	50	53	58	64	67	68	70
2	8	11	12	14	15	19	27	33	40	42	44	45	48
1	1	1	1	1	3	5	8	11	12	14	15	14	16

Semantic Verbal Fluency

To determine the effect of the sociodemographic variables on the scores of the Animal, Fruit and Professions categories, three multiple linear regression models were performed. The independent variables for these models were: age, age2, and sex, while the dependent variables were the score of Animals, Fruits and Professions. To generate normative data, we used the final multiple linear regression and residual standard deviations of each of the categories. For each multiple linear regression model, the assumptions of multicollinearity, normality, homoscedasticity and the existence of influential values were evaluated.

Table 5a shows the results of the three final multiple linear regression models for the scores of the Animals, Fruits and Professions categories. The multiple linear regression model for the animal category was significant (p <0.001) and explained 8.4% of the variance of this score. The variables age, and age2 had a significant effect on the score of the animal category, where a curvilinear increase in scores was observed up to approximately 50 years (Figure 5a). The variables sex was not significant.

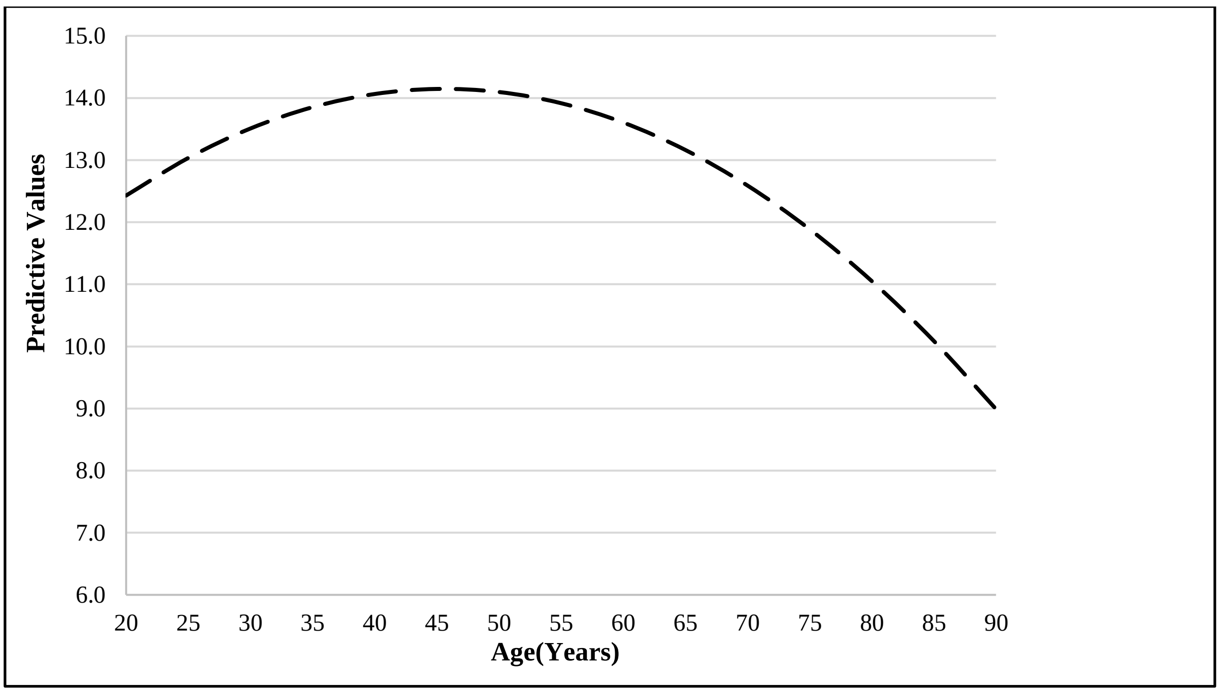
Table 5a. Final Multiple Linear Regression Models for the Semantic Verbal Fluency Scores

Test		**B**	**Std. Error**	***T***	**Sig.**	**R^2**	***SDe* (residual)**
Animals	(Constant)	12.383	0.297	41.672	<0.001	0.084	4.1567
	Age-60.92	-0.073	0.013	-5.733	<0.001		
	$(Age-60.92)^2$	-0.002	0.001	-3.888	<0.001		
Fruits	(Constant)	10.834	0.272	38.878	<0.001	0.094	3.3176
	Age-60.92	-0.055	0.010	-5.453	<0.001		
	$(Age-60.92)^2$	-0.002	0.000	-3.391	<0.001		
	Sex	-0.876	0.344	-2.544	0.011		
Professions	(Constant)	6.759	0.170	39.703	<0.001	0.035	3.4047
	Age-60.92	-0.035	0.009	-3.782	<0.001		

Table 5b
Standard Deviation Residuals for the Semantic Verbal Fluency

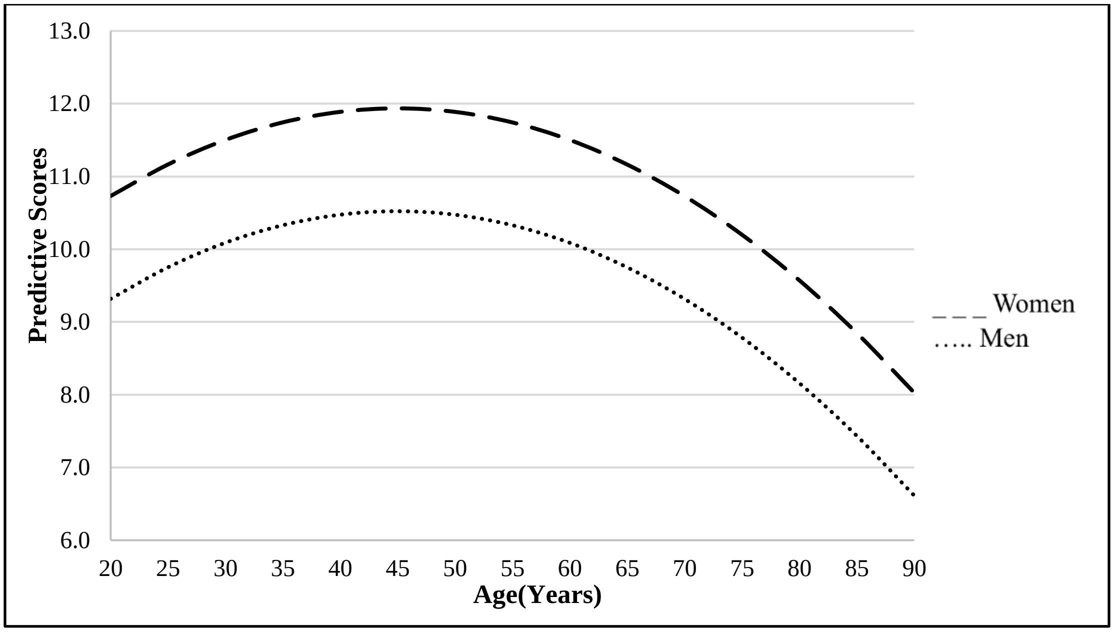
	Predictive Value	Standard Deviation Residual
Animals	≤10.746	3.941
	10.747-11.854	4.015
	11.855-12.683	4.519
	≥12.684	4.163
Fruits	For any value	3.304
Professions	For any value	3.410

Figure 5a. Predictive Scores of the Animal Category



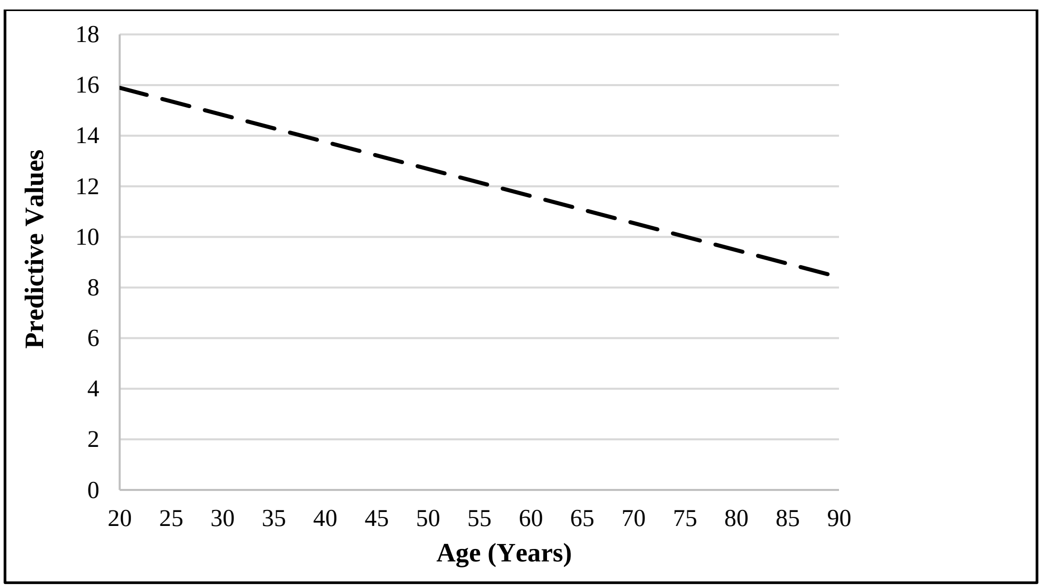
The final multiple linear regression model for the Fruits category was significant (p <0.001) and explained 9.4% of the variance of this score. It was found that the variables age, age2 and sex had a significant effect on the score of the Fruits category, where a curvilinear increase in scores was observed up to approximately 50 years (Figure 5b) and that women scored higher than men.

Figure 5b. Predictive Scores of the Fruits Category



The final multiple linear regression model for the Professions category was significant (p <0.001) and explained 2.9% of the variance. It was found that the variables age had a significant effect on the score of the Professions category, where younger people obtained higher scores than the older individuals, showing a linear decline in the scores according to age (Figure 5c)

Figure 5c. Predictive scores of the Professions category



The verification of assumptions for the multiple linear regression models showed that the three final models had homoscedasticity of the residual values (p's> 0.01). The multiple linear regression models for the Animals categories (K-S=0.040, p=0.170) and Fruits (K-S=0.025, p=0.200) had a normal distribution of the residual values, except for the Animals category model (K-S=0.070; p<0.001), therefore, it was necessary to create an empirical cumulative distribution of the standardized z-values (See Table 5b). The three final models did not present multicollinearity (FIV values were less than 10, FIV≤1.234, collinearity tolerance values did not exceed the value of 1) and there were no influential cases (Cook's maximum distance value was 0.068).

Normative Data for the Semantic Verbal Fluency Test

To facilitate the compression of the normative data procedure, an example is provided. Suppose you want to know the percentile of a woman who is 50 years of age, and who scored 11 in the Fruits category. To obtain the percentile, the following steps should be followed:

1. Calculate the predictive value for the fruits category using the following formula:

$$\hat{Y}_i = b_0 + b_1 \bullet (Age - 60{,}9)_i + b_2 \bullet (Age - 60{,}9)_i^2 + b_3 \bullet Sex$$

Using Table 5a you can obtain the information needed for each beta values part of this formula. The beta values of the variables age, age2 and sex must be replaced in the formula. The sex variable was coded as 1 if they were men and 0 if they were women, and since the person in our example is a man, the value will be Sex=1. Therefore, the formula would be:

$$\hat{Y}_i = 10.834 + [-0.055 \bullet (Age - 60.9)_i] + [-0.002 \bullet (Age - 60.9)_i^2] + [-0.876 \bullet Grupo]$$

$$\hat{Y}_i = 10.834 + [-0.055 \bullet (50 - 60.9)] + [-0.002 \bullet (50 - 60.9)^2] + [-0.876 \bullet 0]$$

$$\hat{Y}_i = 11.66.$$

2. Calculate the residual value e_i. To do this, a subtraction must be made between the direct score of the Fruits category that the participant has achieved (Y_i) and the predictive value ($\hat{Y}_i$) as shown below:

$e_i = Y_i - \hat{Y}_i$

$e_i = 11 - 11.67$

$e_i = -0.67$

3. Transform residual value into z_i score. For this purpose, it is necessary to consult the column SD_e in Table 5b and take the specific value of the Fruits category, which is 3.30. With this value, we proceed to transform the residual value to score z_i using the following equation:

$z_i = e_i / SD_e$

$z_i = -0.67 / 3.304$

$z_i = -0.202$

4. Convert the z_i score to the exact percentile. In the case of the Fruits category, the standardized residual values have a normal distribution, so any of the following tools must can can be used to find the percentile: 1) the normal cumulative distribution tables (Strauss et al., 2006) or 2) online calculators (e.g., http: //www.measuringu.com/pcalcz/). In this example, the percentile for the value of z_i= -0.202 using an online calculator is a percentile of 41.99th.

Use of Normative Data Tables for the Semantic Verbal Fluency Test

Normative data for the Semantic Verbal Fluency tests will be presented in tables with approximate percentiles (Table 5c, Table 5d and Table 5e). For the generation of said tables, the four-step procedure described in the methodology of this study was used. Continuing with the previous example, using Table 5c to obtain the approximate percentile of a 50-year-old woman who scored 11 in the Fruits category, we have to first look for the participant's age (50 years) that is in the range between 48-52 years, and then down the column to find the closet direct score to our participant (11). For this example, using the table, a woman that is 50 years of age who scored 11 in the Fruits category has a percentile of 40th.

Table 5c. Normative Data for the Fruits Category by Age and Sex

		Percentile	Age (Years)											
			18-22	23-27	28-32	33-37	38-42	43-47	48-52	53-57	58-62	63-67	68-72	73-77
Men	**1.64**	**95**	14.303	14.796	15.189	15.482	15.675	15.768	15.761	15.654	15.447	15.14	14.733	14.226
	1.28	**90**	13.108	13.601	13.994	14.287	14.48	14.573	14.566	14.459	14.252	13.945	13.538	13.031
	1.04	**85**	12.312	12.805	13.198	13.491	13.684	13.777	13.77	13.663	13.456	13.149	12.742	12.235
	0.84	**80**	11.649	12.142	12.535	12.828	13.021	13.114	13.107	13	12.793	12.486	12.079	11.572
	0.52	**70**	10.587	11.08	11.473	11.766	11.959	12.052	12.045	11.938	11.731	11.424	11.017	10.51
	0.255	**60**	9.708	10.201	10.594	10.887	11.08	11.173	11.166	11.059	10.852	10.545	10.138	9.631
	0	**50**	8.862	9.355	9.748	10.041	10.234	10.327	10.32	10.213	10.006	9.699	9.292	8.785
	-0.25	**40**	8.032	8.525	8.918	9.211	9.404	9.497	9.49	9.383	9.176	8.869	8.462	7.955
	-0.52	**30**	7.137	7.63	8.023	8.316	8.509	8.602	8.595	8.488	8.281	7.974	7.567	7.06
	-0.84	**20**	6.075	6.568	6.961	7.254	7.447	7.54	7.533	7.426	7.219	6.912	6.505	5.998
	-1.04	**15**	5.412	5.905	6.298	6.591	6.784	6.877	6.87	6.763	6.556	6.249	5.842	5.335
	-1.28	**10**	4.615	5.108	5.501	5.794	5.987	6.08	6.073	5.966	5.759	5.452	5.045	4.538
	-1.64	**5**	3.421	3.914	4.307	4.6	4.793	4.886	4.879	4.772	4.565	4.258	3.851	3.344
Women	**1.64**	**95**	15.179	15.672	16.065	16.358	16.551	16.644	16.637	16.53	16.323	16.016	15.609	15.102
	1.28	**90**	13.984	14.477	14.87	15.163	15.356	15.449	15.442	15.335	15.128	14.821	14.414	13.907
	1.04	**85**	13.188	13.681	14.074	14.367	14.56	14.653	14.646	14.539	14.332	14.025	13.618	13.111
	0.84	**80**	12.525	13.018	13.411	13.704	13.897	13.99	13.983	13.876	13.669	13.362	12.955	12.448
	0.52	**70**	11.463	11.956	12.349	12.642	12.835	12.928	12.921	12.814	12.607	12.3	11.893	11.386
	0.255	**60**	10.584	11.077	11.47	11.763	11.956	12.049	12.042	11.935	11.728	11.421	11.014	10.507
	0	**50**	9.738	10.231	10.624	10.917	11.11	11.203	11.196	11.089	10.882	10.575	10.168	9.661
	-0.25	**40**	8.908	9.401	9.794	10.087	10.28	10.373	10.366	10.259	10.052	9.745	9.338	8.831
	-0.52	**30**	8.013	8.506	8.899	9.192	9.385	9.478	9.471	9.364	9.157	8.85	8.443	7.936
	-0.84	**20**	6.951	7.444	7.837	8.13	8.323	8.416	8.409	8.302	8.095	7.788	7.381	6.874
	-1.04	**15**	6.288	6.781	7.174	7.467	7.66	7.753	7.746	7.639	7.432	7.125	6.718	6.211
	-1.28	**10**	5.491	5.984	6.377	6.67	6.863	6.956	6.949	6.842	6.635	6.328	5.921	5.414
	-1.64	**5**	4.297	4.79	5.183	5.476	5.669	5.762	5.755	5.648	5.441	5.134	4.727	4.22

Table 5d. Normative Data for the Animals Category by Age

z	Percentile	Age (Years)											
		18-22	23-27	28-32	33-37	38-42	43-47	48-52	53-57	58-62	63-67	68-72	>73
95	**1.786**	19.446	19.849	20.152	20.355	20.458	20.461	20.364	20.167	19.87	19.473	18.976	18.379
90	**1.312**	17.476	17.879	18.182	18.385	18.488	18.491	18.394	18.197	17.9	17.503	17.006	16.409
85	**0.982**	16.104	16.507	16.81	17.013	17.116	17.119	17.022	16.825	16.528	16.131	15.634	15.037
80	**0.742**	15.107	15.51	15.813	16.016	16.119	16.122	16.025	15.828	15.531	15.134	14.637	14.04
70	**0.476**	14.001	14.404	14.707	14.91	15.013	15.016	14.919	14.722	14.425	14.028	13.531	12.934
60	**0.188**	12.804	13.207	13.51	13.713	13.816	13.819	13.722	13.525	13.228	12.831	12.334	11.737
50	**-0.071**	11.728	12.131	12.434	12.637	12.74	12.743	12.646	12.449	12.152	11.755	11.258	10.661
40	**-0.335**	10.631	11.034	11.337	11.54	11.643	11.646	11.549	11.352	11.055	10.658	10.161	9.564
30	**-0.591**	9.567	9.97	10.273	10.476	10.579	10.582	10.485	10.288	9.991	9.594	9.097	8.5
20	**-0.908**	8.249	8.652	8.955	9.158	9.261	9.264	9.167	8.97	8.673	8.276	7.779	7.182
15	**-1.056**	7.634	8.037	8.34	8.543	8.646	8.649	8.552	8.355	8.058	7.661	7.164	6.567
10	**-1.179**	7.123	7.526	7.829	8.032	8.135	8.138	8.041	7.844	7.547	7.15	6.653	6.056
5	**-1.396**	6.221	6.624	6.927	7.13	7.233	7.236	7.139	6.942	6.645	6.248	5.751	5.154

Table 5e. Normative Data for the Professions Category Stratified by Age

z	Percentile	Age (Years)											
		18-22	23-27	28-32	33-37	38-42	43-47	48-52	53-57	58-62	63-67	68-72	>73
95	**1.789**	14.131	13.971	13.811	13.651	13.491	13.331	13.171	13.011	12.851	12.691	12.531	12.371
90	**1.342**	12.603	12.443	12.283	12.123	11.963	11.803	11.643	11.483	11.323	11.163	11.003	10.843
85	**1.039**	11.57	11.41	11.25	11.09	10.93	10.77	10.61	10.45	10.29	10.13	9.97	9.81
80	**0.802**	10.759	10.599	10.439	10.279	10.119	9.959	9.799	9.639	9.479	9.319	9.159	8.999
70	**0.462**	9.598	9.438	9.278	9.118	8.958	8.798	8.638	8.478	8.318	8.158	7.998	7.838
60	**0.096**	8.351	8.191	8.031	7.871	7.711	7.551	7.391	7.231	7.071	6.911	6.751	6.591
50	**-0.08**	7.749	7.589	7.429	7.269	7.109	6.949	6.789	6.629	6.469	6.309	6.149	5.989
40	**-0.345**	6.843	6.683	6.523	6.363	6.203	6.043	5.883	5.723	5.563	5.403	5.243	5.083
30	**-0.603**	5.963	5.803	5.643	5.483	5.323	5.163	5.003	4.843	4.683	4.523	4.363	4.203
20	**-0.872**	5.044	4.884	4.724	4.564	4.404	4.244	4.084	3.924	3.764	3.604	3.444	3.284
15	**-0.98**	4.676	4.516	4.356	4.196	4.036	3.876	3.716	3.556	3.396	3.236	3.076	2.916
10	**-1.14**	4.13	3.97	3.81	3.65	3.49	3.33	3.17	3.01	2.85	2.69	2.53	2.37
5	**-1.436**	3.118	2.958	2.798	2.638	2.478	2.318	2.158	1.998	1.838	1.678	1.518	1.358

Hopkins Verbal Learning Tests- Revised (HVLT-R)

To determine the effect of the sociodemographic variables on the HVLT-R total score, HVLT-R Deferred Recall and HVLT-R Recognition, three multiple linear regression models were performed. The independent variables for these models were age, age2, and sex, while the dependent variables were the Total score, the Deferred Recall and the Recognition of the HVLT-R. To generate normative data, the final multiple linear regression model and residual standard deviations were used. For each multiple linear regression model, the assumptions of multicollinearity, normality, homoscedasticity and the existence of influential values were evaluated.

Table 6a shows the results of the three final multiple linear regression models of the HVLT-R. The final multiple linear regression model for the HVLT-R total recall was significant ($p < 0.001$) and explained 14.8% of the variance of this score. The variables age and age2 had a significant effect on the HVLT-R total recall score, where a curvilinear increase in scores was observed up to approximately 50 years (Figure 6a). The sex variable was not significant, thus no included in the final model. The final multiple linear regression model for HVLT-R Recognition was significant ($p < 0.01$) and explained 3.1% of the variance of this score. Variables age had a significant effect on the score of the HVLT-R Recognition, showing a linear decline in the scores according to age (Figure 6b). The variables sex, and age2 were not significant. The final multiple linear regression model for the HVLT-R Delayed Recall was significant ($p < 0.001$) and explained 3.7% of the variance of this score. The variables age had a significant effect on the score of the HVLT-R Delayed Recall, showing a linear decline in the scores according to age (Figure 6c). The variables sex, and age2 were not significant.

Table 6a. Final Multiple Linear Regression Models for the HVLT-R

Test		**B**	**Std. Error**	***T***	***Sig.***	***R²***	***SDe* (residual)**
HVLT-R Total Recall	(Constant)	14.801	0.342	4.326	<0.001	0.148	4.290
	Age-60.92	-0.094	0.013	-7.296	<0.001		
	(Age-60.92)^2	-0.002	0.001	-3.910	0.001		
HVLT-R Delayed Recall	(Constant)	9.698	0.121	80.399	<0.001	0.037	2.373
	Age-60.92	-0.025	0.007	-3.852	<0.001		
HVLT-R # Recognition	(Constant)	2.160	0.086	26.263	<0.001	0.031	1.629
	Age-60.92	0.016	0.005	3.391	<0.001		

Figure 6a. Visual Representation of curvilinear effect for the HVLT-R Total Recall

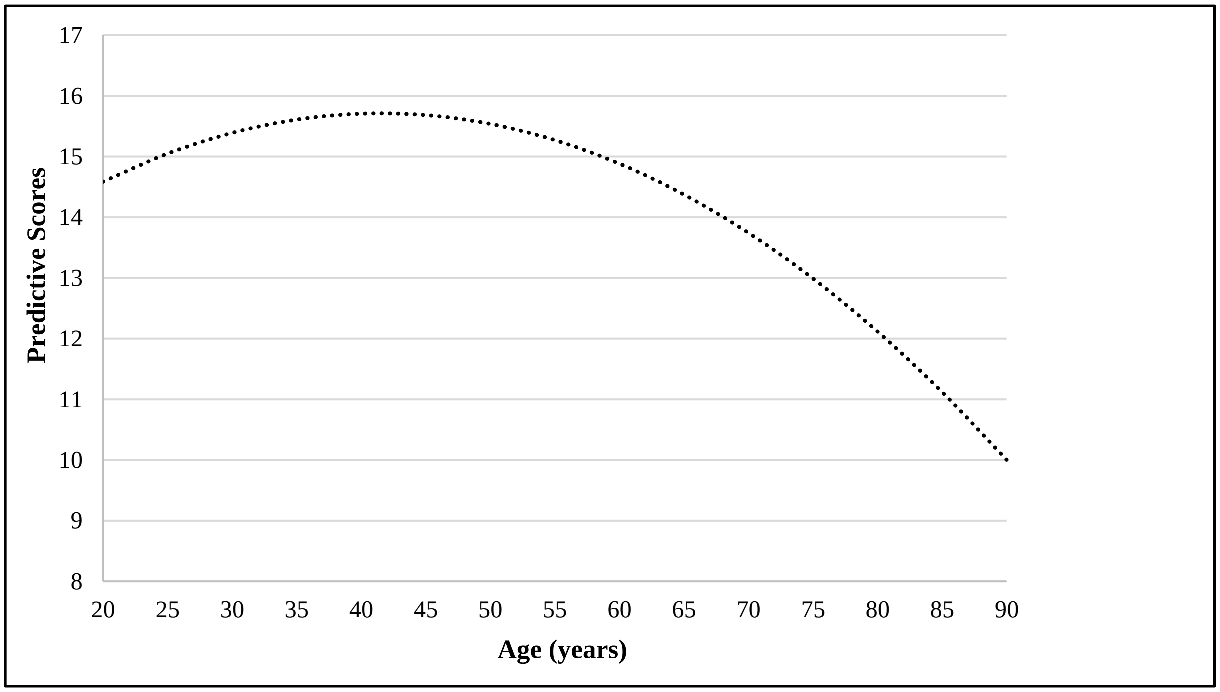


Figure 6b. Predictive scores of HVLT-R Delay Recall

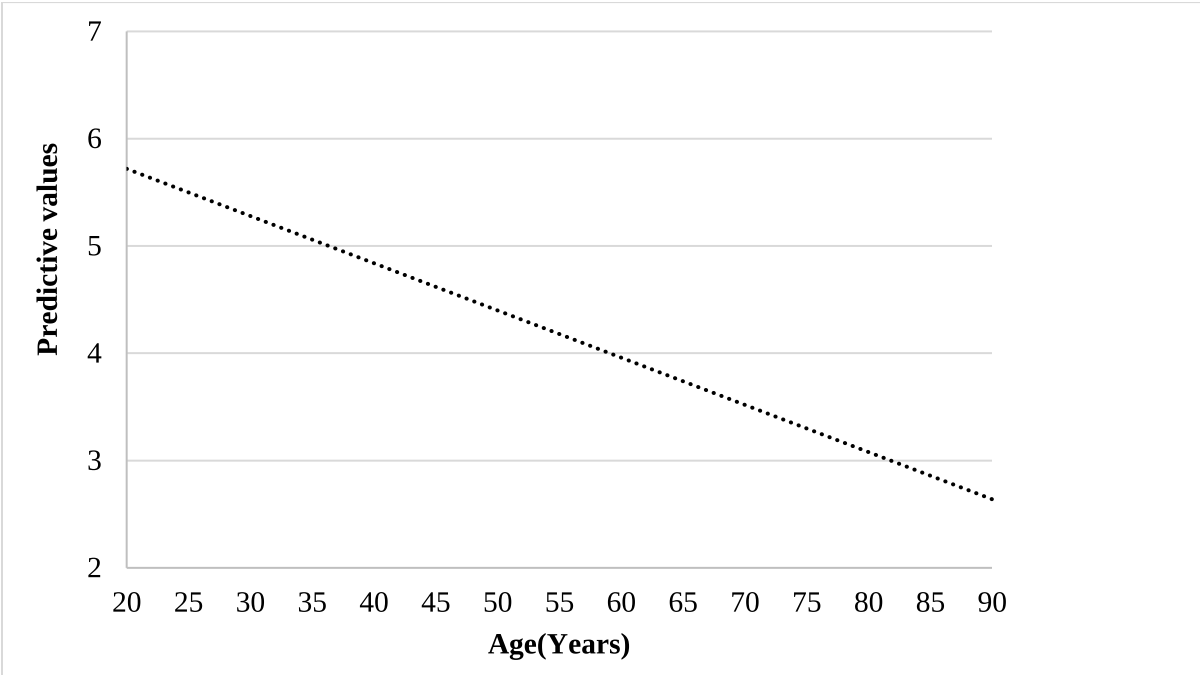
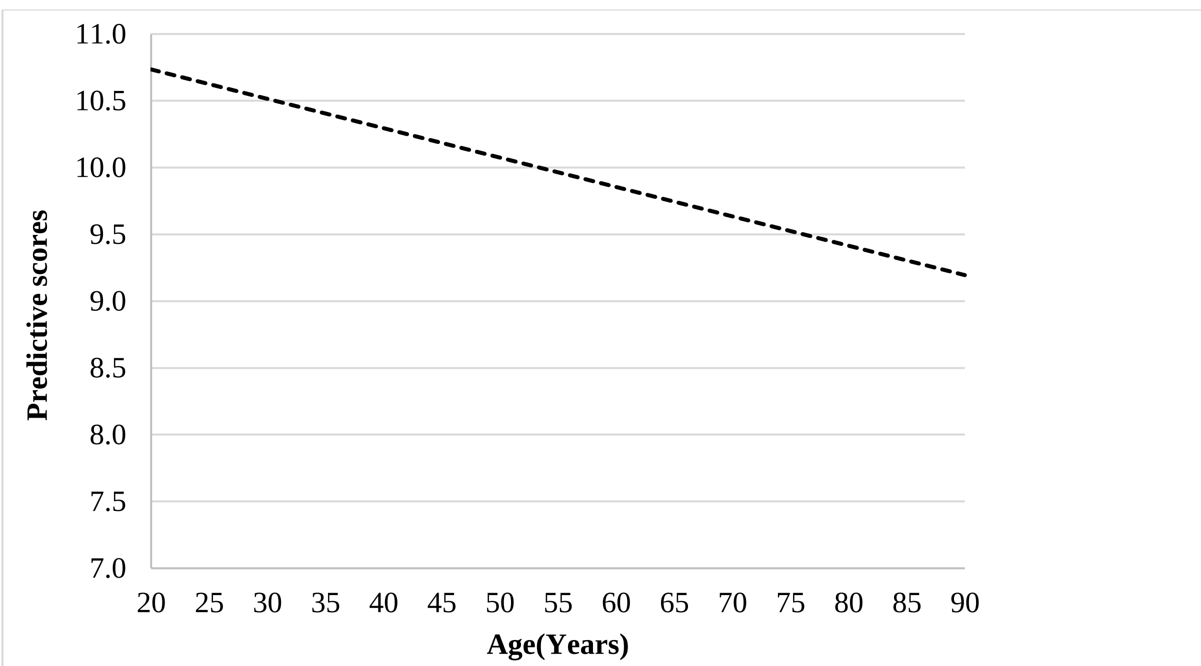


Figure 6c. Predictive scores of HVLT-R Recognition



The assumptions verifications for the multiple linear regression analysis showed the HVLT-R Total Recall had a normal distribution of the standardized residual values, except for the HVLT-R Recognition (K-S=0.068, p <0.001) and Delayed Recall (K-S=0.124, p<0.001), therefore, it was necessary to estimate the standard deviation residual for each of the ranges of the predictive values as shown in Table 6b. The three models showed homoscedasticity according to the Levene test, and absence of multicollinearity (the VIF values were less than 10, FIV≤1.000, the collinearity tolerance values did not exceed the value of 1). There were no influential cases (the maximum distance from Cook was 0.045)

Table 6b.
Standard Deviation Residuals for the HVLT-R

	Predictive Value	**Standard Deviation Residual**
HVLT-R Total	For any value	4.290
HVLT-R Delayed Recall	≥9.319	2.776
	9.320-9.633	2.305
	9.634-10.022	2.475
	≥10.023	1.851
HVLT-R Recognition	≤1.958	1.595
	1.9597-2.200	1.539
	2.2015-2.396	1.567
	≥2.397	1.804

Normative Data for the HVLT-R

To simplify the understanding of the procedure to obtain the percentile associated with the scores of each test, an example will be provided. Suppose you need to find the percentile of a 50-year-old individual, and who scored a 21 on the HVLT-R Total Recall. The steps to obtain the percentile for this score are: 1) Find Table 6a, which contains the final multiple linear regression model for the recognition test. Use the *B* weights to create an equation ($\hat{Y}_i = b_0 +$

$b_1 \bullet \ (Age - 60.9)_i + b_2 \bullet (Age - 60.9)_i^2$) that will allow you to obtain the predicted score for the test. In this case, sex was not a significant predictor, and therefore not included in the equation.

The equation would be as follows: $\hat{y_i} = 14.801 + [-0.094 \cdot (50 - 60.9)] + [-0.002 \bullet (50 - 60.9)_i^2]$. Thus, the predicted value equation is: $\hat{y_i}$= 12.588. In order to calculate the residual value (indicated with an e_i in the equation), we subtract the direct total recall test score (21) from the predicted value we just calculated ($e_i = \ y_i - \ \hat{y_i}$). In this case, it would be $e_i = \ 21 - 15.5887 = 5.412$. Next, refer the *SD*$_e$ column in Table 6b to obtain the specific *SD*$_e$ (residual) value for Total Recall. Using this value, we can transform the residual value to a standardized *z* score using the equation $(e_i \ / SD_e)$. In this case, we have $5.412/4.290 = 1.261$. 4) The last step is to use the tables available in most statistical reference books (e.g., Strauss, Sherman, & Spreen, 2006) or an online calculator (e.g., ttp://www.measuringu.com/pcalcz/) to convert *z* scores to percentiles. In this example, and using an online calculator, the *z* score (probability) of 1.262 corresponds to the 89.65th percentile.

Use of Normative Data Tables for the HLVL-R Test

The four-step normative procedures explained above offers the clinician the ability to determine the percentile for an individual who are illiterate and who has a specific score on the four neuropsychological tests presented here. Nevertheless, this method can be prone to human error due to the number of hand calculations necessary and it could be slow and time-consuming. For this reason, and to enhance user-friendliness, this dissertation will present user friendly tables for the HVLT-R (Table 6c, Table 6d and Table 6e) using the four-step procedure explained above, for clinicians to more easily obtain a percentile range/estimate associated with a given direct score on this test.

In order to obtain an approximate percentile for the example presented above (converting a direct score of 21 on Total Recall for a 50 year old individual) Table 6c must be used. First, identify the appropriate table ensuring the appropriate test (Total Recall, Delayed Recall and Recognition). Second, find the appropriate age of the individual, in this case, 50 years. Third, look in the "48-52" years' age column to find the approximate location of the direct score obtained on the test. Within the 48-52 years' column, the score of 21 obtained by this individual corresponds to an approximate percentile of 30.

Table 6c. Normative Data for HVLT-R Total Recall Stratified by Age

z	Per	Age (Years)											
		18-22	**23-27**	**28-32**	**33-37**	**38-42**	**43-47**	**48-52**	**53-57**	**58-62**	**63-67**	**68-72**	**>73**
95	**1.640**	22.856	23.19	23.43	23.57	23.60	23.546	23.384	23.122	22.760	22.298	21.736	21.074
90	**1.280**	21.273	21.61	21.84	21.98	22.02	21.963	21.801	21.539	21.177	20.715	20.153	19.491
85	**1.040**	20.219	20.55	20.79	20.93	20.97	20.909	20.747	20.485	20.123	19.661	19.099	18.437
80	**0.840**	19.340	19.67	19.91	20.05	20.09	20.030	19.868	19.606	19.244	18.782	18.220	17.558
70	**0.520**	17.933	18.27	18.50	18.64	18.68	18.623	18.461	18.199	17.837	17.375	16.813	16.151
60	**0.250**	16.747	17.08	17.32	17.46	17.49	17.437	17.275	17.013	16.651	16.189	15.627	14.965
50	**0.000**	15.648	15.98	16.22	16.36	16.40	16.338	16.176	15.914	15.552	15.090	14.528	13.866
40	**-0.250**	14.549	14.88	15.12	15.26	15.30	15.239	15.077	14.815	14.453	13.991	13.429	12.767
30	**-0.520**	13.362	13.70	13.9	14.07	14.11	14.052	13.890	13.628	13.266	12.804	12.242	11.580
20	**-0.840**	11.956	12.29	12.53	12.67	12.70	12.646	12.484	12.222	11.860	11.398	10.836	10.174
15	**-1.040**	11.077	11.41	11.65	11.79	11.82	11.767	11.605	11.343	10.981	10.519	9.957	9.295
10	**-1.280**	10.022	10.36	10.59	10.73	10.77	10.712	10.550	10.288	9.926	9.464	8.902	8.240
5	**-1.640**	8.440	8.778	9.016	9.154	9.192	9.130	8.968	8.706	8.344	7.882	7.320	6.658

Table 6d. Normative Data for HVLT-R Delayed Recall Stratified by Age

Direct Score	Age (Years)											
	18-22	23-27	28-32	33-37	38-42	43-47	48-52	53-57	58-62	63-67	68-72	>73
12	100	100	100	--	--	--	--	--	--	--	--	--
11	99	99	99	100	100	100	100	--	--	--	--	--
10	97	98	98	99	99	99	99	100	100	100	100	100
9	93	94	95	96	97	97	98	98	99	99	99	99
8	84	87	89	90	92	93	95	96	96	97	98	98
7	72	75	78	81	83	86	88	90	91	93	94	95
6	55	59	63	66	70	73	76	79	82	84	87	89
5	37	41	45	49	53	57	61	64	68	71	74	78
4	22	25	28	32	35	39	43	47	51	55	58	62
3	11	13	16	18	21	24	27	30	33	37	41	45
2	5	6	7	9	10	12	14	17	19	22	25	28
1	2	2	3	4	4	5	7	8	9	11	13	15

Table 6e. Normative Data for HVLT-R Recognition Stratified by Age

Direct Score	**Age (Years)**											
	18-22	**23-27**	**28-32**	**33-37**	**38-42**	**43-47**	**48-52**	**53-57**	**58-62**	**63-67**	**68-72**	**>73**
12	73	75	79	81	84	87	89	91	93	94	96	97
11	50	52	54	57	59	63	66	67	70	72	75	78
10	29	31	32	34	36	39	41	46	48	50	52	54
9	15	16	17	18	18	20	20	23	25	29	31	32
8	7	7	8	9	9	10	11	12	13	15	16	17
7	3	4	4	5	5	5	6	6	6	7	7	8
6	2	2	2	2	2	2	2	2	3	3	4	4
5	1	1	1	1	1	1	1	1	1	2	2	2
≤4	1	1	1	1	1	1	1	1	1	1	1	1

Discussion

The objective of this dissertation was to generate normative data of four neuropsychological tests (ROCF, M-WCST, HVLT-R and, Semantic Verbal Fluency) for a sample of individuals who are illiterate and from Latin America corrected by demographic variables such as age, and sex (if appropriate). Prior to generating the normative data for each of the tests, a number of independent sample t-tests were performed to figure out if type of illiteracy (absolute vs. functional) and country (Colombia vs. Others) had significant effects in our data. Even though a number of these were significant none reached a large size effect stated by Cohen's *r* to subsequently generate normative tables by either country or illiteracy type. In addition psychometric analysis of reliability, and construct validity were performed. The analyzes demonstrated that the neuropsychological tests studied guarantee good reliability in the sample of individuals who are illiterate and from Latin America, both in Cronbach's alpha values ($\alpha > 0.697$) and intraclass correlation coefficients ($r > 0.697$), all with 95% confidence intervals (95% CI) which reached optimal values (Muñiz, 2005).

In regards to the tests' construct validity, a very common technique was used for large sample sizes (e.g., Stevens et al., 2013), in which 50% of the sample was randomly selected to perform an EFA and then, with the remaining 50% of the sample, the model resulting from the EFA was confirmed through a CFA. In this case, it was possible to confirm a factor model demonstrating that each item has factors loading in the right direction for each of the four corresponding tests. For example, each of the scores for the M-WCST (total error, perseverations and correct categories) had high confirmatory factor loadings for all cases ($\Lambda > 0.976$) and with adequate signs according to the M-WCST factor. The same can be observed for the HVLT-R, verbal fluency and the ROCF. Reliability for all four tests were similar to those coming from educated populations, suggesting the use of these tests to be reliable in illiterate populations as well (i.e., 0.86 vs. 0.83 [Prieto et al., 2010] for the ROCF test, 0.85 vs. 0.82 for the M-WCST [Scheretlen et al., 2007], 0.78 vs. 0.83 [Tombaugh et al., 1999] for the Semantic Verbal fluency).

Once the reliability and validity of the tests in the population of individuals who are illiterate were established, multiple linear regression models were carried out for each of the tasks that make up each neuropsychological test to determine the effect of the demographic variables (age and sex) and as a correction method to generate normative data. Assumptions of multicollinearity, homoscedasticity, normality and influential values were also checked for each test. First, the multicollinearity assumptions in each model were tested (11 models). The results show that there was no multicollinearity between the predictor variables in the final models according to the tolerance and VIF values. Second, the majority of tests indicated homoscedasticity, except for the ROCF Memory and the M-WCST Correct Categories, for these tests the residual standard deviation (SD_e) was estimated in each of the predictive scores quartiles in order to compensate for the lack of homoscedasticity in the model and to have greater precision in the generation of normative data. On the other hand the majority of the tests did not show a normal distribution (except for the M-WCST Total Errors, Animals, Fruits and the HVLT-R total recall), thus an empirical distribution function was used for the transformation of z_i to percentile. Finally, influential values were not found in the final models of all tests.

The final multiple linear regression models for the ROCF showed an effect of age for both the memory and copy tasks, showing a linear decline, as participants get older. However, the variables sex was only shown to be significant for the ROCF Copy, where older men had higher scores than older women. For this reason normative data tables for only the ROCF Copy were separated by gender. A wide variety of studies have also found that ROCF Copy and

Memory scores decrease with age (Chervinsky et al., 1992; Meyers & Meyers, 1995a; Rosselli & Ardila, 1991) and that man score better than women, but overall gender differences are minor or non-existent (Berry et al., 1991; Peña-Casanova et al., 2009). One study suggested that longer copy time could be associated with better memory scores in women, but with worse immediate recall performance in men. It is possible that longer copy time may reflect increased attention to detail or meticulousness in women, whereas it could be a sign of impairment in men (Tremblay et al., 2014) however further research is needed as literature is inconclusive on regards to gender differences in general.

The amount of time/velocity taken to copy the ROCF could be clearly identified as cultural value (Ardila, 2005). Many cultural groups in Latin America, the concept of speed and quality are contradictory, where a good product is considered as the result of a slow and careful process, something quite contrary to what is observed in other countries, where the best performance is usually associated with a higher response speed (Ardila, 2007).

Regarding the M-WCST, the final multiple linear regression models revealed only an effect of age, for both Correct Categories and Total Errors, showing a linear decline of correct categories and an increase of errors, as subjects get older. It is important to note the final model for M-WCST Perseverations was not significant, thus normative data for this portion of the test was not developed. Similar results are observed in demographic effects for the M-WCST presented by Arango-Lasprilla et al. (2015d), Caffarra et al. (2004), Lineweaver et al. (1999), Obonsawin et al. (1999), Schretlen, 2010, and Wang et al. (2011), where age had a negative impact on performance (fewer correct categories, higher number of total errors as people get older). Finally, and in agreement with that reported in the literature (Arango-Lasprilla et al., 2015d, Caffarra et al., 2004), no effect of sex was found on the M-WCST scores.

The Animals and Fruits categories of the semantic verbal fluency test had an effect of quadratic age, meaning a curvilinear increase in scores was observed up to approximately 50 years of age. A linear decline was only seen for the Professions category, where older people obtained lower scores than younger individuals. In addition, only the Fruits category showed an effect of sex, where women scored higher on this test than men. Studies report a possible sociocultural explanation that, regardless of primary language, women outperformed men on "vegetable" and "fruits" categories, due to the fact that, in the US as in Latin American countries, women are more likely to be involved in food procurement and preparation than men, as reported in many other studies with educated samples in Latin America (Acevedo et al., 2000; Bolla, Gray, Resnick, Galante, & Kawas, 1998; Capitani, Laiacona, & Barbarotto, 1999; Contador et al., 2016; Peña-Casanova et al., 2009).

The final multiple linear regression models for the HVLT-R revealed a predictive effect of the variable age, for Total Recall, Delayed Recall and Recognition scores, showing a linear decline, as people get older. However, only the Total Recall scores showed a predictive effect for quadratic age, meaning a curvilinear increase in scores was observed up to approximately 50 years of age. The results coincide with a number of studies where age influenced the performance of HVLT-R (younger individuals presented a higher performance in this test; Arango-Lasprilla et al., 2015e; Brandt & Benedict, 2001; Cherner, et al., 2007, Friedman et al., 2002; Hester et al. 2004; Miotto et al., 2012),

There are several studies that have aimed to obtain normative data for a number of neuropsychological tests in countries such as the US (Cherner et al., 2007, Duff, 2016, Friedman et al., 2002, Norman et al., 2011; Vanderploeg et al., 2000), Colombia (Rivera et al., 2015), Argentina, Bolivia, Chile, Cuba, El Salvador, Guatemala, Honduras, Mexico, Paraguay, Peru, Puerto Rico (Arango-Lasprilla et al., 2015) and Australia (Hester et al., 2004). However, these studies are limited to educated populations, language (e.g., Portuguese [Leite, Miotto, Nitrini, & Yassuda, 2017]), geographic area (e.g., only Mexico [Ostrosky-Solís, Gómez-Pérez, Matute, Rosselli, Ardila, & Pineda 2007], age (e.g., 65 and older [Contador et al., 2016]) sample size (e.g., 32 [Kim & Na, 2004]) and use of normative data techniques (e.g., Some do not consider abnormal distributions of residuals for the calculation of percentiles [Acevedo et al., 2000; Alegret et al., 2012; Butman et al., 2000]).

Despite the importance of all these studies aiming to obtain normative data in different populations, only a number of studies (11) have provided normative data for individuals who are illiterate. This is, with no doubt, a major limitation of the results since, despite the majority of these neuropsychological tests being frequently used by neuropsychologists in Latin America, there are no data to compare the performance of individuals who are illiterate. Thus normative data cannot be used in this population, especially considering the great influence of education on performance in cognition.

In the last three years, normative data studies done in Latin America, with educated samples, have developed norms using multiple linear regression models in which sociodemographic variables such as age, sex and education are included as predictors. When generating normative data using this method (Guàrdia-Olmos et al., 2015a, Rivera & Arango, 2017, Van der Elst, Hurks, Wassenberg, Meijs & Jolles, 2011) a series of advantages over traditional methods exist, such as: 1) knowing which variables (sociodemographic and/or clinical) significantly predict a score in a neuropsychological test (greater validity), 2) control the collinearity of the predictive variables, 3) explore more than one type of function (linear vs. quadratic) in variables and 4) detect the violations of the statistical assumptions for each one of the multiple linear regression models. This methodology allows the researcher to correct norms as necessary, in order to have greater precision when developing norms. Due to these advantages, the current dissertation used the same methodology to develop normative data, but in a sample of individuals who are illiterate and from Latin America.

Due to the variety of methods used to develop adjusted normative data, different distributions presentations, and the limited data specifically for individuals who are illiterate, it is impractical to make direct comparison. However, to overcome these limitations, a series of comparisons have been made using practical examples and the user-friendly normative data tables for each of the tests studied by Olabarrieta-Landa, (2015a) and Rivera et al., (2015) in 11 Latin American countries, since it uses a similar method for correction to the one used in this dissertation.

Example 1. Lets assume we have a 50-year-old female who produced 15 words in the animal's category of the Semantic Verbal Fluency test. According to the normative tables presented by Olabarrieta-Landa et al. (2015a) with educated populations, a person with the same demographic characteristics (low education; 1-12 years of education vs. <12 years of education) would be located in the following percentiles (by country; see Table 7a):

Table 7a. Example of percentiles from example 1 of the Animals test

Population	Percentile	Performance
Argentina	30	Low
Bolivia	60	Medium
Chile	50	Medium
Cuba	50	Medium
El Salvador	60	Medium
Guatemala	30	Low
Honduras	50	Medium
Mexico	30	Low
Paraguay	90	High

Peru	40	Low

According to the normative data generated for the illiterate population in this study, a person with these demographic characteristics would be located at a 70th percentile, indicating a high performance. However, an important difference is observed when its score is compared with normative data from Argentina, Bolivia, Chile, Cuba, El Salvador, Guatemala, Honduras, Mexico, Paraguay and Peru, where this person would obtain percentiles that would indicate low, medium or very high performance (Paraguay).

Example 2. Lets assume we know the percentile of a 60-year-old man and who has taken score in the M-WCST Correct Categories are three. According to the normative tables presented by Rivera et al., (2015), a person with these demographic characteristics would be located in the following percentiles (by country; See table 7b):

Table 7b. Example of percentiles from example 2 of the M-WCST Categories test

Population	Percentile	Performance
Argentina	<4	Very low
Bolivia	20	Low
Chile	5	Low
Cuba	20	Low
El Salvador	50	Medium
Guatemala	30	Low
Honduras	60	Medium
Mexico	20	Low
Paraguay	5	Low
Peru	40	Low

In the present dissertation a person with these demographic characteristics would have a percentile of 50, indicating a medium performance in this neuropsychological test. In terms of percentiles, the only country in which this person would obtain a similar percentile is El Salvador and Honduras, while in the other countries it would obtain different percentiles, either very low percentiles (Argentina) or low.

As a result of these comparisons, important differences in the values of the percentiles can be observed in the two examples presented. This difference confirms the importance of generating normative data corrected by demographic variables for populations who are illiterate. On the other hand, not having normative data for neuropsychological tests in this population could lead to bad practices in the process of evaluation, rehabilitation and patient follow-up (Ardila, 1995, 1998). These differences may have different explanations, among which are cultural and socioeconomic differences between countries, differences in literacy rates of men and women, or the control of multicollinearity factors in the multiple linear regression models.

Implications

This dissertation is part of a larger study of normative data for neuropsychological tests carried out to date in Latin America. For this reason, it should be seen as a first step for further studies on normative data and representative data at a national level. The use of multiple linear regressions and residual standard deviation has shown to be a more accurate method for the generation of normative data in neuropsychological tests, for this reason, the results presented in this dissertation provide normative data updated and adjusted to the demographic characteristics of populations who are illiterate in Latin America. These results help overcome one of the main barriers that prevent the proper development of neuropsychology in Latin America, taking into account that a high percentage of professionals who use these neuropsychological tests take as a use normative data from other countries. Having normative data for a number these neuropsychological tests in a population of individuals who are illiterate will allow the improvement of good practices in both the clinic and research. Ultimately, the patients themselves will be the most benefited, since now, more precise diagnoses can be made and, in turn, they may be referred to rehabilitation programs according to a proper diagnosis. Finally, professionals in Latin America may use the results presented in this dissertation, as it is necessary to evaluate and diagnose individuals who are illiterate.

Limitations and future directions

Despite the importance of the results of this dissertation, these norms must be interpreted taking into account the following limitations. First, all the participants in this study spoke Spanish as their native language, however, no data was obtained related to the level of bilingualism in the sample, which has an effect on a person's cognitive performance and could potentially be different for people who speak a secondary language. In Latin America a great variety of languages exist (e.g., Nahualt, the Witoto, among other languages). The present dissertation present normative data for only four neuropsychological tests (the ROCF, M-WCST, HVLT-R and Verbal Fluency), however two more neuropsychological test (i.e., Brief Test of Attention and the Symbol Digit Modalities Test), collected as part of the original study will soon be published in a book called *Neuropsioclogia y Analfabetizmo* (i.e., Rivera, Morlett-Paredes & Arango-Lasprilla, 2018). Future researchers should consider creating normative to other neuropsychological tests in order to increase the number of standardized normative data in this population.

The sample was limited to populations from only six countries in Latin America, which means that the normative data of this study cannot be generalized for other countries where individuals who are illiterate also reside. It is important to note that even though a large effect of country (Colombia vs. Other) was not found in this study, a number of normative data studies performed in educated populations in Latin America did find differences by country (e.g., Arango et al., 2015c; Rivera et al., 2015a). The effect of culture on the performance of neuropsychological tests is widely known (Lezak, 2004, Strauss et al., 2006). Thus, further studies should collect more data in illiterate populations from different countries to further research the potential of country differences. The purpose of the original study was not to collect data on illiterate populations, however after data cleaning, the idea of developing data for this population emerged. Even though we had a total sample of 388 individuals, sample size was small for some countries (e.g. Peru; n=1). Future research should develop a plan to target data collection in illiterate populations not only in Latin America, but other parts of the world where illiteracy is still a concern. Research efforts should use particular sources and influential persons and organizations in the community to reach this subgroup. Indicating particular sources of information that could be used to influence particular illiterate individuals (i.e., people trust messages that come from others who are similar in age, ethnicity, etc.). Also, indicating how the particular channels of influence can be used to reach this population (e.g., Latinos/Hispanics might be reached through church bulletins in their traditional faith communities).

In addition, clinical samples or participants with a history of neurological diseases were not evaluated, which prevented the performance of discriminant validity and obtaining predictive cut-off points for the neuropsychological tests studied. On the other hand, the information regarding neurological and psychiatric diseases of the participants was obtained through self-report. It is possible that someone with a history of some diseases could have been included in the sample despite the screening tests. The sample consisted of a population between 18 and 90 years of age, which excluded the majority of teenagers. This population should be taken into account to generate normative data in future studies since it is a very important population in Latin America that tends to drop out of school in order to work and provide to their families.

Another very important variable that should be measured in future research is the quality of education, which could have a great influence on cognitive performance.

Even though the focus of this dissertation is on individuals deemed illiterate from Latin America, it is important to acknowledge the need for research for Latino individuals whom are illiterates living in the US. According to the latest statistics of the Education Attainment by the US Census Bureau (U.S. Census Bureau), 246,325 adults (i.e., all races 18 years and over) in the US have zero years of education and of those 39,170 are identified as Hispanic. Differences in neuropsychological test performance between literate and illiterate groups in the US should also raise concerns regarding their appropriateness due to cultural factors (e.g., acculturation level, language, bilingualism) for the potential risk of misdiagnosis, as norms for neuropsychological tests are still limited for these individuals in the US. Cherner and, colleagues (2007) developed normative data for two (i.e., BVMT-R and HVLT-R) neuropsychological tests in sample of Spanish-speaking individual from the US. In this study, Cherner highlights that existing norms are particularly inadequate for individuals with lower levels of education (e.g. participants with 6 or fewer years of education fell within the impaired range, using a cut point of one standard deviation below the mean). This validates the needs for norms in Latino populations in the US, but those deemed illiterate as well.

Bilingualism is an important variable to take into consideration, being that it occurs in several Latin American countries as a result of linguistic heterogeneity. In the case of individuals who are illiterate, the majority tends to live in more rural geographic areas, which presents great linguistic differences not only within the Spanish language, but the variety of dialects in those territories. These other dialects can belong to indigenous societies which present cultural differences much more marked than those found in other countries of the American continent

(Landaburu, 2004).

Future research may further elucidate the optimal methods for improving diagnostic assessment and develop appropriate norms for those Latinos living in the US who are considered illiterate. For the time being, I would recommend the use of the current normative data, as it is the closest to the cultural and linguistic reality of Latinos in the US. This study highlights the importance of normative data tailored to the characteristics of a specific population. Having accurate normative data which are adjusted to the characteristics of individuals who are illiterate will help clinicians more accurately interpret the results of their neuropsychological assessments, which in turn will help to increase the accuracy of resultant diagnoses and allow for the delivery of appropriately tailored treatments and interventions to various groups of neurologic patients. In conclusion, the results of this study are a first step towards the standardization of other instruments that are used frequently in Latin America and that to date do not have normative data updated to the demographic and current methodological characteristics.

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