The NeuroBel: A screening test for oral language impairment in Spanish-speaking elderly people

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Abstract

Purpose: The NeuroBel is a screening test that allows the evaluation of oral comprehension and language production deterioration in the elderly. This study replicated previous research using larger clinical samples from three Spanish-speaking countries. **Method**: Eight tasks were used to analyze oral language functioning using a psycholinguistic approach. Two-hundred and thirty-two elderly, monolingual Spanish speakers from Spain, Cuba, and Colombia participated in this study. Of these, 76 had Alzheimer's disease (AD) in the initial phase, 75 had mild cognitive impairment (MCI), and 81 did not have cognitive impairment (controls). **Results:** Significant differences were observed between the three clinical groups. The participants with AD had significantly worse NeuroBel scores. The MCI group had significantly lower scores than did the control group. Discriminant analysis showed that 83.2% of the participants were correctly classified into the groups that were originally selected. The NeuroBel showed a high correlation with the Mini-Mental Score (.87) and a high sensitivity in the determination of AD and cognitive deterioration. The area under the ROC curve was .97 in contrast to AD vs. MCI + Controls and .96 in the determination of cognitive deterioration (AD + MCI vs. controls). The canonical discriminant functions and precision cut-offs from the ROC analyses are also shown in the results. **Conclusions**: This study confirms that the NeuroBel is a reliable screening test for the detection of cognitive-linguistic impairment in Spanish-speaking elderly people.

Introduction

Life expectancy has increased in most societies worldwide over the past decades. Correspondingly, the prevalence of aging-related disfunctions, as mild cognitive impairment, MCI, and neurocognitive disorders (previously named as 'dementias') has also increased, such is the case of Alzheimer Disease (AD) (Bermejo & Del Ser, 1993; Garre-Olmo, 2018; OMS, 2015; Prince et al., 2015; WHO, 2019). AD is the most frequent form of cognitive disorder among elderly people (circa 70% of the total cases), doubling the risk every five years from 60 years on (Alzheimer's Association, 2020; Dubois & Uspenskaya-Cadoz, 2016). AD evidences memory deficits, but also in other cognitive domains, as language.

MCI— also named as mild neurocognitive disorder, mNCD, in DMS-5 (Sach-Ericsson & Blazer, 2014)— refers to cognitive difficulties that appears with aging (Flicker et al., 1991) in one or more cognitive domains, but that does not compromise patient's independence and self-sufficiency may be preserved with greater efforts or adaptative strategies. Main difference between mild and major neurocognitive disorders, as AD, is the degree of functional interference of the cognitive disfunction with day-to-day activities, which is related to the severity of the symptoms. Importantly, MCI may, or may not, progress to AD (Roberts & Knopman, 2013)), depending on several factors, including MCI subtype (amnesic vs not amnesic; for a review, Roberts & Knopman, 2013), so that, in some cases, exploring MCI may facilitate the understanding of insidious initial stages and progression of AD (Maestú et al., 2015; Xu et al., 2021).

Language is one of the cognitive domains that can be affected in cognitive disorders (APA, 2013), and an essential ability. It represents a reflex of the general cognitive function, that could evidence its progressive deterioration in AD and/or MCI (Pulsifer et al., 2020) and in normal aging (Juncos-Rbadán, 1998); components such as memory or executive functions may be altered, influencing language comprehension and expression. Therefore, the difficulties in language are related to cognitive impairments. Its decline may affect normal communication skills, in particular language production (Shake & Stine-Morrow, 2017).

Moreover, in those cases in which MCI may progress to AD is important to detect preclinical signs associated with cognitive decline, as key elements for early prevention and interventions (Albert et al., 2001). For instance, in preclinical states, and related to language in MCI, has been observed grammatical simplification and difficulties with sentence organization, loss of vocabulary in naming, errors in the identification and description of thematic images, understanding of more elaborate syntactic structures and reading comprehension, among others (Cuetos et al., 2007; Forbes et al., 2002, 2004, 2005; Garrard et al., 2005; Pulsifer et al., 2020; Tsantali et al., 2013).

Very interestingly, language deficits are heterogeneous in different sub-processes, depending on the neural condition *per se*. For instance, aging: tends to decline especially the lexical-access (Kavé & Goral, 2017), probably underlaying decreased brain activity (Cuetos, 2003); weakens phonology domain more than semantic (Burke & Shafto, 2004); reduces syntax in people over 70 years of age, either in complexity, in particular in those with little schooling levels (Kemper et al., 2001; 2004), as in organizing sentence's elements (Obler & Pekkala, 2008). In contrast, in normal aging, semantic remain intact; as well as the understanding the passive vocabulary (Shake & Stine-Morrow, 2017; Wingfield et al., 1991; Wingfield & Stine, 1991); and even concept definitions can be richer and more precise (Kavé & Yafé, 2014).

Although is commonly accepted that aging tends to reduce cognitive functions, including language, as a whole, reality is more heterogeneous and we need tools to evaluate language sub-domains with enough sensibility and specificity to detect normal aging vs pathological states related to aging in elders (as AD and MCI). Attempts to evaluate language characteristics in this population are becoming widespread in clinical practice (Zheng et al., 2022), in particular in AD (Petti et al., 2020). However, the screening tests available, and most frequently used by specialists, to evaluate possible language deterioration in aging are verbal fluency tasks, which can be quantitatively (Nutter-Uphama et al., 2008; Rinehardt et al., 2014; Tsantali et al., 2013) or qualitatively evaluated (Paeka & Murrayb, 2021). But mere assessment of verbal fluency is not sufficient to specify which aspects of language processing are affected by cognitive decline in aging and which aspects remain preserved for a longer period, in spite its utility for subsequent interventions. In addition, most of the clinical tests available to assess putative pathological language features during aging have been developed in the United States or the United Kingdom, with native English speakers (e.g., Bayles & Tomoeda, 2019, 2020; Bryan et al., 2001; Dooley & Walshe, 2019; Ferris et al., 2009; Helm-Estabrooks, 2017; Krein, 2019); there is less in other languages, as Spanish, which represents more than 500 million native speakers (Eberhard et al., 2019).

Short, easy-to-administer language tests are extremely useful and necessary for daily clinical practice, as the deterioration of this cognitive function is among the firsts to appear in many cognitive neurodegenerative diseases (Albert et al., 2011; Radanovic & Mansur, 2011). Also, these tests should enable the early detection of signs that differentiate normal aging from potentially pathological aging, and the level and sub-domains at which linguistic deficits occur (e.g. if they are due to phonological aspects, word identification, access to lexicon, semantic, etc.).

In this context, Adrián et al. (2015) developed a new short test (NeuroBel) for the initial evaluation of the psycholinguistic processes involved in the comprehension and oral production of Spanish. In a later study with a group of 50 Spanish-speaking patients, Bermúdez-Llusá et al. (2019) confirmed that the NeuroBel is a valid and reliable screening test for measuring aging-related language impairments in people diagnosed with AD and MCI. The results provided important baseline values and initial cutoff points to differentiate participants with cognitive impairment due to MCI or AD from those with nonpathological aging. These results indicate that the NeuroBel is a reliable instrument for detecting oral language impairment in adults.

Despite these promising initial findings, further research was needed for standardization. For example, the sensitivity and specificity of the NeuroBel should be assessed with samples drawn from a variety of Spanish-speaking countries. Standardization of the NeuroBel is important given the polysemic value and diversity of Spanish vocabulary among the different Spanish-speaking geographical areas.

Thus, the present study replicated the work of Bermúdez-Llusá et al. (2019) using larger clinical samples drawn from various Spanish-speaking countries. The main objective was to verify the reliability of the NeuroBel as a tool to screen for language impairment in elderly individuals, taking into account possible dialect variations among Spanish-speaking countries. These results may offer relevant cross-cultural data for the correct standardization and use of this screening test.

Method

Participants

A total of 232 monolingual Spanish speakers (62 men and 170 women; 59-92 years of age) who resided in Spain (n = 75), Cuba (n = 75), and Colombia (n = 82) participated in this study. The education levels of the participants ranged from functional illiteracy (less than one year of schooling) to 17 years of formal education (mean = 9.0 years; SD = 4.3). Of the total sample, 151 were diagnosed with AD in the initial stage or MCI stage according to the clinical criteria of the Global Deterioration Scale (GDS) (Reisberg et al., 1982). The remaining 81 participants served as the control group (elderly individuals with normal aging and without observable cognitive impairment) and were matched to the group of patients with MCI in terms of sex, age, and years of education. The evaluations were carried out in collaboration with health care, clinical, and research centers in the countries included in this study. The criteria for the selection, inclusion and exclusion of the participants, and administration of the tests were agreed upon and standardized among the different centers and collaborating countries in this study.

Table 1 shows the sociodemographic characteristics and MMSE scores of the participants according to clinical group and country of origin. The MMSE is a test frequently used in clinical research to evaluate the cognitive status of a patient and rule out a possible diagnosis of dementia.

As shown in Table 1, the clinical groups (the AD and MCI groups) were similar in terms of sex, age, and years of education. In contrast, and as expected, there were significant differences among groups in MMSE scores. Significant differences among countries of origin were observed only in years of education (see the bottom of Table 1).

Participants were selected according to their medical records, with confirmation that their diagnosis corresponded to one of the two clinical groups evaluated in this study as necessary. These medical records included different neuropsychological batteries to explore different areas of cognition (e.g., memory and fluency), geriatric reports, and (for some patients) neuroimaging data used to confirm the clinical diagnoses of the participants. The inclusion criterion for the AD group was a GDS score of 4 (Reisberg et al., 1982), that for the MCI group was a GDS score of 3, and that for the control group was a GDS score of 1 or 2 (see Leon & Reisberg, 1999 for more detail). The exclusion criteria were as follows: (a) severe vision or hearing difficulties, (b) a GDS score ≥ 5, (c) an MMSE score < 16 points (the lower limit of moderate cognitive deficit), (d) a history of neurological or psychiatric illness, or e) depressive symptoms (score > 9 on the Spanish version of the 9-item Patient Health Questionnaire (PHQ-9) (Kroenke et al., 2001). The PHQ-9 was used to identify whether a patient suffered from depression at the time of cognitive evaluation. It is widely used by specialists to identify undiagnosed depression.

Instruments

The NeuroBel consists of eight tasks that assess the essential components of oral language processing in comprehension and production, from the most peripheral to the most central (Adrián et al., 2015). A detailed explanation of the scoring rules for each task in the test is provided in Appendix A. Likewise, different dialectic meanings were used to designate objects and actions according to the countries included in this study. Appendix B includes a table with a list of the words used in different countries that were accepted as valid for scoring some NeuroBel tasks.

The NeuroBel is conceptually based on the EPLA (Valle & Cuetos, 1995), which is the Spanish version of the Psycholinguistic Assessments of Language Processing in Aphasia (PALPA) (Kay, Lesser, & Coltheart, 1992), and on the BETA (Cuetos & González- Nosti, 2009); however, it employs different tasks, stimuli, and items. Therefore, the NeuroBel is not a modified version or shortened form of these tests. The NeuroBel includes eight tasks: four tasks that explore comprehensive or receptive language, and four that explore expressive or productive language in oral communication.

The linguistic stimuli (words) used for some of the NeuroBel tasks (i.e., the *auditory lexical decision*, *spoken word to picture matching*, *object naming*, and *action naming* tasks) were selected from the *Diccionario de frecuencias de las unidades lingüísticas del castellano* ("*Dictionary of frequencies of Spanish linguistic units*") (Alameda & Cuetos, 1995).

Procedure

This study was approved by the Ethics Committee of the University of Malaga (Comité Ético de la Universidad de Málaga [CEUMA]: 78-2016-H).

The participants in the AD and MCI groups were recruited from the Municipal Center for Healthy Aging of Malaga and Virgen del Carmen Residence for the Elderly in Estepona (Spain), Associations of Relatives of Alzheimer's Patients of Malaga (AFA) and Estepona, Aging and Health Center (CITED) of Calixto García Hospital in Havana (Cuba) and various centers and residences for elderly individuals in Barranquilla (Colombia). The control group consisted of individuals without cognitive impairment from the aforementioned centers and friends and relatives of patients who volunteered to participate in this study.

The evaluator explained the purpose of the study to each participant, and each participant was asked to sign an informed consent form. All participants who met the inclusion criteria were evaluated using the NeuroBel. Correct responses to the items on the test tasks were recorded. The evaluation began by providing each participant with instructions for each task. The evaluator ensured that each participant understood each task by demonstrating 1-2 examples of the task.

Statistics

Data analysis was performed using Statistical Package for the Social Sciences (SPSS version 28.0) software (IBM Corporation Business Analytics Software portfolio, Chicago, USA). The means and standard deviations of the NeuroBel task scores, including the total score, were calculated separately for each group.

Univariate analysis of NeuroBel total scores, with *country* as a covariate, was performed to determine possible differences among the AD, MCI, and control groups. Multivariate analyses of variance (MANOVAs; using Pillai's trace values) and Tukey's honestly significant difference (HSD) post hoc tests were performed to identify significant differences among the groups in performance on the NeuroBel tasks.

Discriminant analysis was also performed to construct a canonical linear predictive model of group membership using NeuroBel tasks as independent variables.

The sensitivity and specificity of the NeuroBel, including true positives (identification of cognitive impairment) and false positives (incorrect labeling of healthy controls); its accuracy and efficacy, according to the area under the curve (AUC); and the optimal cutoff points (CP), established using receiver-operating characteristic (ROC) curve analysis, were also calculated.

Results

The NeuroBel had adequate internal consistency (Cronbach's alpha = .77) and a strong correlation with MMSE scores (Pearson’s $r = .87$, $p < .01$).

Group comparisons

Figure 1 shows the mean NeuroBel total scores for the three clinical groups (the AD, MCI, and control groups) and the three countries (Spain, Cuba, and Colombia) considered in this study. Table 2 presents the mean scores and standard deviations by group for each NeuroBel task.

Univariate analysis, controlling for *country* as a covariate, was used to compare the NeuroBel total scores among the groups. There was a significant main effect of group on NeuroBel total scores ($F\ (2, 231) = 341.75$, $p < .001$; $\eta_p^2 = .750$). The main effect of *country* was not significant ($F\ (2, 231) = 2.01$, $p < .157$; $\eta_p^2 = .009$) and did not explain variance in NeuroBel total scores among the groups.

The MANOVA results ($F\ (2, 231) = 20.49$, $p < .001$; $\eta_p^2 = .424$) using Pillai's trace indicated significant differences in NeuroBel task scores among the groups analyzed. Post hoc analysis using Tukey's HSD indicated significant differences ($p < .05$) between the AD group and the other two groups (the MCI and control groups) on 7 out of 8 of the NeuroBel tasks ($p < .001$); no significant group differences were observed in the *repetition* task. There were significant differences ($p < .05$) between the MCI and control groups in six out of eight of the NeuroBel tasks ($p < .001$); there were no significant differences between these groups on the *auditory lexical decision* and *repetition* tasks.

Discriminant analysis

Table 3 (upper panel) shows the structure of the canonical matrix of discriminant functions. The NeuroBel task scores (set as variables) were ordered by the size of the correlation within each function, which provided the best possible discrimination among the groups. Discriminant Function 1 indicated the tasks that best differentiated the three groups in this study (the AD, MCI, and control groups), and Function 2 showed the differences among the groups after controlling for Function 1. Function 2 also highlighted the tasks that were irrelevant to distinguishing among the groups (*auditory lexical decision*) as well as the less important or not very distinguishing tasks (*phoneme discrimination* and *repetition*) and the highly relevant tasks for distinguishing among groups *(sentence completion*), especially between the MCI and control groups. These results support those obtained in the post hoc analyses, with the *auditory lexical decision* and *repetition* tasks less relevant for distinguishing among the groups. The reclassification results of the discriminant analysis, which was conducted to determine the coherence of the data obtained with the data originally used to determine the groups (the AD, MCI, and control groups), are shown in the lower panel of Table 3. The results indicated that 83.2% of participants were correctly classified into their original groups.

Sensitivity and specificity of the NeuroBel: ROC curve analysis

The ROC curve in Figure 2 shows the rate of true positives (participants correctly identified as having cognitive-linguistic impairment; sensitivity) versus the rate of false positives (participants incorrectly identified as having cognitive-linguistic impairment; specificity). Figure 2 also shows the precision of NeuroBel total scores in terms of the ROC curve and the AUC, indicating differentiation between the AD group and MCI + control groups (left) and between the AD + MCI groups and control group (right). For the detection of AD, the NeuroBel had a sensitivity of .97 and a 1-specificity of .81 (AD vs. MCI + control), and for the detection of MCI, the NeuroBel had a sensitivity of .98 and a 1-specificity of .70 (AD + MCI vs. control). The AUC was .97 for the AD group vs. the MCI + control groups and .96 for the AD + MCI groups vs. the control group.

Regarding the cutoff points for the different groups, a NeuroBel score ≥ 90.25 points indicated performance in the typical or normal range of the population (i.e., lack of cognitive-linguistic deterioration), a score between 84.25 and 90 points indicated performance typical of an individual with MCI, and a score of < 84.25 points indicated a performance typical of an individual with AD.

Discussion

The NeuroBel battery explores the effects of aging on oral language abilities and the relationship between aging and cognitive decline. In this study, the NeuroBel scores of Spanish-speaking populations from various countries were analyzed. Data collected in Spain, Cuba, and Colombia indicated that the NeuroBel is a reliable tool for screening oral language impairment in patients diagnosed with AD and MCI.

This study replicated the results of Bermúdez-Llusá et al. (2019) with a larger sample size. The results obtained provide valuable reference values and cutoff points for clinical practice to identify patients with possible cognitive-linguistic impairment.

The univariate analysis of NeuroBel total scores indicated that this test detected significant differences among the groups studied, regardless of their country of origin (which did not explain the observed variance). The AD group had significantly lower NeuroBel total scores (75.92/100) than the MCI group (85/100) and control group (92.42/100). Healthy participants (the control group) had significantly higher scores than those with cognitive impairment (in the AD and MCI groups).

Analysis of the NeuroBel task scores by group with a MANOVA revealed significant differences. A post hoc test indicated that the AD group performed significantly worse than the MCI and control groups on 7 out of 8 tasks evaluated. Performance on the *repetition* task did not significantly differ among the groups, suggesting that repeating words or pseudowords is irrelevant to the diagnosis of oral language impairment during aging. This assumption was supported by the post hoc results comparing the MCI and control groups, as performance on the *repetition* and *auditory lexical decision* tasks did not significantly differ between the two groups. The MANOVA results were confirmed with discriminant analysis (Table 3). The tasks associated with semantic and syntactic processing (*sentence completion*, *action naming*, *object naming* and *auditory sentence comprehension*) appeared to be the most relevant and predictive within the discriminant matrix. The discriminant matrix correctly categorized more than 80% of the participants into their original groups. The *sentence completion* task appeared especially important for clinical discrimination, confirming the key role of the frontal lobe in morphosyntactic planning and the formation of meaningful sentences from a previously given word (see Cai et al., 2008; Voets et al., 2005). In contrast, most of the tasks that evaluate nonsemantic (sublexical) skills appeared less important (*spoken word to picture matching* and *phoneme discrimination*) or irrelevant *(repetition* and *auditory lexical decision*) for differentiating the three groups of participants.

The present results confirm those of Bermúdez-Llusá et al. (2019) and reinforce the conclusions of previous studies that lexical-semantic processing and syntax are the first oral language competences affected in the initial phases of cognitive deterioration in individuals with MCI and AD (Arango-Lasprilla et al., 2003; 2007; Cuetos et al., 2003; 2009; Garrard et al., 2005; Jones et al., 2006; Obler & Pekkala, 2008; Radanovic & Mansur, 2011, Small et al., 1997).

The ROC curve analysis results shown in Figure 2 indicate that the NeuroBel has "very good" (Hosmer et al., 2013; Pepe, 2003) sensitivity for language impairment in aging. Thus, the NeuroBel is an appropriate test for clinical screening of oral language deficits in Spanish-speaking individuals due to cognitive decline during aging. The AUC indicated that the probability that a participant with AD would score lower than participants with MCI or control participants was 97%. Similarly, the probability that a participant with cognitive impairment (AD or MCI) would obtain a NeuroBel score lower than control participants was 96%.

The NeuroBel cutoff points provide valuable clinical information to specialists for determining whether the elderly individual evaluated falls within or outside of normal ranges, the latter of which could indicate possible language impairment. However, the specificity (false-positive rate) of the NeuroBel was lower, indicating reduced discriminative capacity to detect the absence of MCI in healthy subjects (1-specificity = .70). This result indicates that up to 30% of healthy subjects could be diagnosed with MCI (i.e., a false-positive result) using the NeuroBel. However, it is important to emphasize that the NeuroBel is a test in which good sensitivity (the true-positive rate) is key; in general, specificity is not as crucial. Thus, we believe that this issue does not reduce the clinical utility of the NeuroBel as a screening tool for language impairment. Its high sensitivity (.97) and good specificity (.81) in distinguishing AD participants from health participants and those with MCI as well as in detecting cognitive impairment (AD or MCI) are clearly relevant for clinical practice. Therefore, in its current form, the NeuroBel seems to be a suitable screening test for early detection of language impairment in aging. Nevertheless, complementary neuropsychological and medical tests should be administered when drawing diagnostic conclusions.

Early detection of cognitive-linguistic deterioration can help professionals (such as neuropsychologists and speech-language pathologists) implement interventions (cognitive stimulation) to delay the insidious progression of cognitive impairment in dementia (Qualls, 2005). In fact, a recent meta-analysis showed that cognitive stimulation plays an important role in the improvement and stabilization of a large number of cognitive functions in elderly individuals (Gómez-Soria et al., 2023).

In conclusion, the results obtained in this study, which replicate those of Bermúdez-Llusá et al. (2019), confirm the validity and reliability of the NeuroBel in screening for possible psycholinguistic deficits during cognitive decline in aging. Its high correlation with MMSE scores and its rapid administration make the NeuroBel a useful tool for clinical practice in speech-language pathology.

Limitations and future prospects

It is necessary to note some limitations of the NeuroBel; these limitations should be considered to improve it, achieve complete standardization, and enable more effective and easy administration. For example, some tasks are demonstrably irrelevant in distinguishing between individuals with and without cognitive impairment and may need to be eliminated. Tasks of a sublexical nature, such as *repetition*, *auditory lexical decision*, and *phoneme discrimination*, could be omitted to achieve a more precise and parsimonious tool. Even the *spoken word to picture matching* task, which is not exclusively verbal (involving gnosic-perceptual processing in item selection), could be replaced by tasks that emphasize semantic-syntactic processing (such as understanding sentences or judging the grammaticality of a sentence). Finally, a fine-grained examination of each NeuroBel item included in screening could provide important information regarding which are the most appropriate and informative, facilitating the development of even shorter and more precise versions of the test. Future research should investigate these questions.

Acknowledgments

We would like to thank Javier Adrián-Torres for their help in the design and drawing of some of the graphic materials used in the NeuroBel.

Data Availability Statement

The datasets generated and/or analyzed during this study are not publicly available due to General Data Protection Regulation compliance and legal and ethical limitations, but a limited amount of data can be shared by the corresponding author upon reasonable request.

References

Adrián, J.A., Jorquera, J., & Cuetos, F. (2015). NEUROBEL: Breve batería neuropsicológica de evaluación del lenguaje oral en adultos-mayores. Datos normativos iniciales [NEUROBEL: Brief neuropsychological screening battery of oral language in older adults. First normative data]. *Revista de Logopedia, Foniatría y Audiología*, *35*(3), 101-113. https://doi.org/10.1016/j.rlfa.2014.12.004.

Alameda, J.R., & Cuetos F. (1995). *Diccionario de frecuencias de las unidades lingüísticas del castellano*. Oviedo, Spain: Servicio de Publicaciones de la Universidad de Oviedo.

Albert, M.S., DeKosky, S.T., Dickson, D., Feldman, H.H., Fox, N., Gamst A, Holtzman, D.M., Jagust W.J., Petersen, R.C., Snyder, P.J., Carrillo, M.C., Thies, B., & Phelps, C.H. (2011). The diagnosis of mild cognitive impairment due to Alzheimer´s disease: Recommendations from the National Institute on Aging-Alzheimer´s Association workgroups on diagnostic guidelines for Alzheimer´s disease. *Alzheimer´s & Dementia*, *7*(3), 270-279. https://doi:10.1016/j.jalz.2011.03.008.

Albert, M.S., Moss, M., Tanzi, R., & Jones, K. (2001). Preclinical prediction of AD using neuropsychological tests. *Journal of the International Neuropsychological Society, 7,* 631–639. https://doi: 10.1017/S1355617701755105.

Alzheimer's Association. (2020). Alzheimer's Disease Facts and Figures. Alzheimer's Dementia 16, 391+. https://www.alz.org/media/Documents/alzheimersfacts-and-figures.pdf.

American Psychiatric Association. (2013). Diagnostic and statistical manual of mental disorders (5th ed.). https://doi.org/10.1176/ appi.books.9780890425596.

Arango-Lasprilla, J.C., Cuetos, F., Valencia, C., Uribe, C., & Lopera, F. (2007). Cognitive changes in the preclinical phase of familial Alzheimer´s disease. *Journal of Clinical and Experimental Neuropsychology, 29*(8), 892-900. https://doi.org/10.1080/13803390601174151.

Arango-Lasprilla, J.C., Iglesias, J., & Lopera, F. (2003). Neuropsychological study of familial Alzheimer's disease caused by the mutation E280A in the presenilin 1 gene. *American Journal of Alzheimer's Disease and Other Dementias, 18*, 137–146. https://doi.org/10.1177/153331750301800306.

Bayles, K.A. & Tomoeda, C.K. (2019). *ABCD-2: Arizona Battery for Cognitive-Communication Disorders, Second Edition–Complete Kit*. Austin, Texas: Pro-Ed.

Bayles, K.A. & Tomoeda, C.K. (2020). *Functional Linguistic Communication Inventory-2.* Austin, Texas: Pro-Ed.

Bermejo, F., & Del Ser, T. (1993). *Demencias: conceptos actuales*. Madrid: Díaz de Santos.

Bermúdez-Llusá, G., Adrián, J.A., Arango-Lasprilla, J.C., & Cuetos, F. (2019). NeuroBel: Spanish screening test for oral psycholinguistics disabilities in elderly people with mild cognitive impairment and early-stage Alzheimer’s disease. *Journal of Communication Disorders, 82*, 105943. https://doi.org/10.1016/j.jcomdis.2019.105943.

Bryan, K., Binder, J., Dann, C., Funnell, E., Ramsey, V., & Stevens, S. (2001). Development of a screening instrument for language in older people (Barnes Language Assessment). *Aging & mental health, 5*(4), 371-378. https://doi.org/10.1080/13607860120080332.

Burke, D.M., Mackay, D., Whorthey, J., & Wade, E. (1991). On the tip of the tongue: What causes word finding failures in young and old adults? *Journal of Memory and Language*, *30*, 542-579. https://doi.org/10.1016/0749-596X(91)90026-G.

Burke, D.M., & Shafto, M.A. (2004). Aging and language production. *Current Directions in Psychological Science*, *13*, 21-24. DOI: 10.1111/j.0963-7214.2004. 01301006.x.

Burke, D.M., Whorthey, J., & Martin, J. (1988). I´ll never forget what´s her name: Aging and tip of the tongue experiences in everyday life. In M.M. Gruneberg, P.E. Morris & R.N. Sykes (Eds.), *Practical Aspects of Memory: Current Research and Issues*. Vol. S. Clinical and Education Implications. Chichester: Wiley and Sons.

Cai, Q., Lavidor, M., Brysbaert, M., Paulignan, Y., & Nazir, T.A. (2008). Cerebral lateralization of frontal lobe language processes and lateralization of the posterior visual word processing system. *Journal of Cognitive Neuroscience*, *20*(4), 672-681. https://doi.org/10.1162/jocn.2008.20043.

Carnero-Pardo, C., & Lendínez-González, A. (1999). Utilidad del test de fluencia verbal semántica en el diagnóstico de demencia [The utility of the semantic verbal fluency test in diagnosis of dementia]. *Revista de Neurología*, *29*, 709-714. doi: 10.33588/rn.2908.99233.

Coltheart, M. (2013). *The Cognitive Neuropsychology of Language (Psychology Revivals)*. Abingdon, UK: Psychology Press.

Cuetos, F. (2003). *Anomia: La dificultad para recordar las palabras.* Madrid, TEA Ediciones.

Cuetos, F., Arango-Lasprilla, J.C., Uribe, C., Valencia, C., & Lopera, F. (2007). Linguistic changes in verbal expression: A preclinical marker of Alzheimer's disease. *Journal of the International Neuropsychological Society, 13*, 1-7. Doi: 10.1017/S1355617707070609.

Cuetos, F., & González-Nosti, M. (2009). *BETA. Batería para la Evaluación de los trastornos afásicos: manual*. Madrid: EOS.

Cuetos, F., Martínez, T., Martínez, C., Izura, C. & Ellis, A.W. (2003) Lexical processing in Spanish patients with probable Alzheimer's disease. *Cognitive Brain Research*, 17, 549-561. https://doi.org/10.1016/S0926-6410(03)00169-1.

Cuetos, F., Rodríguez-Ferreiro, J., & Menéndez, M. (2009). Semantic markers in the diagnosis of cognitive impairment in neurodegenerative dementias. *Dementia and Geriatric Cognitive Disorders*, *28*, 267-274. https://doi.org/10.1159/000242438.

Dooley, S. & Walshe, M. (2019). Assessing cognitive communication skills in dementia: a scoping review. *International Journal of Language and*

Communication Disorders, 54 (5), 729-741. https://doi.org/10.1111/1460-6984.12485.

Dubois, B. y Uspenskaya-Cadoz, O. (2016). Changing concepts and new definitions for Alzheimer's disease. In M. Husain y J.M. Schott (Eds.), *Oxford Textbook of Cognitive Neurology and Dementia*. Oxford, UK: Oxford University Press.

Eberhard, D.M., Simons, G.F., & Fennig, C.D. (eds.). (2019). *Ethnologue: Languages of the World.* Twenty-second edition. Dallas, Texas: SIL International. Online version: http://www.ethnologue.com.

Ellis, A. W., & Young, A. W. (2013). *Human Cognitive Neuropsychology: A Textbook with Readings*. Abingdon, UK: Psychology Press.

Everly, J., Plummer, J., Lohman, M., & Neils-Strunjas, J. (2023). A Tutorial for Speech-Language Pathologists: Physical Activity and Social Engagement to Prevent or Slow Cognitive Decline in Older Adults. *American Journal of Speech-Language Pathology, 32*(1), 83-95. DOI: 10.1044/2022_AJSLP-22-00035.

Fernández, T., Ríos, C., Santos, S., Casadelvall, T., Tejero, C., López, E., et al. (2002). «Cosas en una casa», una tarea alternativa a «animales» en la exploración de la fluidez verbal semántica: estudio de validación [“Household ítems”: An alternative task to “animals” in the assessment of semantic verbal fluency. A validation study]. *Revista de Neurología, 35*,520-523. doi: 10.33588/rn.3506.2002027.

Ferrero-Arias J, Sánchez-Saudinós M, Lamet-Gil I. (2001). Five by five test. A brief instrument for the detection of cognitive impediment in clinical settings. *Neurologia, 16*(6):254-261. PMID: 11423042.

Ferris, S., I., R., Robert, P., Winblad, B., Gatz, G., Tennigkeit, F., & Gauthier, S. (2009). Severe Impairment Battery Language scale: a language-assessment tool for Alzheimer's disease patients. *Alzheimer's & Dementia, 5*(5), 375-379. https://doi.org/10.1016/j.jalz.2009.04.1236.

Flicker, C., Ferris, S.H. y Reisberg, B. (1991). Mild cognitive impairment in the elderly: predictor of dementia. Neurology, 41, 1006–1009. DOI: 10.1212/wnl.41.7.1006.

Forbes, K. E, Ellis, A.W., Shanks, M.F., & Venneri, A. (2005). The age of acquisition of words produced in a semantic fluency task can reliably differentiate normal from pathological age-related cognitive decline. *Neuropsychologia*,*43*(11), 1625-32. doi: 10.1016/j.neuropsychologia.2005.01.008.

Forbes, K. E., Shanks, M. F., & Venneri, A. (2004). The evolution of dysgraphia in Alzheimer's disease. *Brain Research Bulletin*, *63*, 19–24. https://doi.org/10.1016/j.brainresbull.2003.11.005.

Forbes, K.E., Venneri, A., & Shanks, M.F. (2002). Distinct patterns of spontaneous speech deterioration: An early predictor of Alzheimer's disease. *Brain and Cognition*, *48*, 356–361. doi: 10.1006/brcg.2001.1377.

Garcés, M., Santos, S., Pérez, C. y Pascual, L. F. (2004). Test del supermercado: datos normativos preliminares en nuestro medio [The supermarket test: Preliminary normative data in our milieu]. *Revista de Neurología*, *39*, 415-448.

Garrard, P., Maloney, L., Hodges, J., & Patterson, K. (2005). The effects of very early Alzheimer's disease on the characteristics of writing by a renowned author. *Brain*, *128*, 250–260. doi:10.1093/brain/awh341.

Garre-Olmo, J. (2018). Epidemiología de la enfermedad de Alzheimer y otras demencias. *Revista de Neurología, 66*(11), 377-386. doi:10.33588/rn.6611.2017519.

Gómez-Soria, I., Iguacel, I., Aguilar-Latorre, A., Peralta-Marrupe, P., Latorre, E., Zaldívar, J.N.C., & Calatayud, E. (2023). Cognitive stimulation and cognitive results in older adults: A systematic review and meta-analysis. *Archives of Gerontology and Geriatrics*, 6(104), 104807. doi:10.1016/j.archger.2022.104807.

Goñi-Sarriés, A., López-Goñi, J.J. David Granados-Rodríguez, D., & González-Jiménez, A. (2015). Edad, escolarización y tareas de Fluencia Verbal para el screening de pacientes con Enfermedad de Alzheimer [Age, schooling and Verbal Fluency tasks for the screening of Alzheimer´s disease patients]. *Anales de Psicología, 31*(3), 773-781. https://doi.org/10.6018/analesps.31.3.168941.

Helm-Estabrooks, N. (2017). *Cognitive-linguistic quick test-plus*. London: Pearson.

Hosmer Jr., D.W., Lemeshow, S. and Sturdivant, R.X. (2013) Applied Logistic Regression. 3rd Edition, John Wiley & Sons, Hoboken, NJ. https://doi.org/10.1002/9781118548387.

Jones, S., Laukka, E., & Backman, L. (2006). Differential verbal fluency deficits in the preclinical stages of Alzheimer’s disease and vascular dementia. *Cortex, 42*, 347–355. https://doi.org/10.1016/S0010-9452(08)70361-7.

Juncos-Rabadán, O. (1998). *Lenguaje y envejecimiento: bases para la intervención.* Barcelona: Masson.

Juncos-Rabadán, O., Facal, D., Lojo-Seoane, C., & Pereiro, A. X. (2013). Does tip-of-the-tongue for proper names discriminate amnestic mild cognitive impairment? *International Psychogeriatrics*, *25*(4), 627-634. DOI: 10.1017/S1041610212002207.

Juncos-Rabadán, O., Rodríguez, N., Facal, D., Cuba, J., & Pereiro, A. X. (2011). Tip-of-the-tongue for proper names in mild cognitive impairment. Semantic or post-semantic impairments? *Journal of Neurolinguistics, 24*(6), 636-651. https://doi.org/10.1016/j.jneuroling.2011.06.004.

Kavé, G., & Goral, M. (2017). Do age-related word retrieval difficulties appear (or disappear) in connected speech? *Neuropsychology, development, and cognition. Section B, Aging, neuropsychology and cognition*, *24*(5):508-527. doi: 10.1080/13825585.2016.1226249.

Kavé, G., & Yafé, R. (2014). Performance of Younger and Older Adults on Tests of Word Knowledge and Word Retrieval: Independence or Interdependence of Skills? American Journal of Speech-Language Pathology, 23, 36–45. DOI: 10.1044/1058-0360(2013/12-0136).

Kay, J., Lesser, R., & Coltheart, M. (1992). *Psycholinguistic Assessments of Language Processing in Aphasia (PALPA).* Hove, UK: Lawrence Erlbaum.

Kemper S. & Sumner, A. 2001. “The structure of verbal abilities in young an older Adults”. *Psychology and Aging, 16*, 312-322.

Kemper, S., Herman, R. & Liu, Ch. 2004. “Sentence production by young and older adults in controlled contexts”. *Journal of Gerontology: Psychological Science, 59B*, 230- 234.

Kemper S., Thompson, T. & Marquis, J. (2001). Longitudinal change in language production: Effects of aging and dementia on grammatical complexity and propositional content. *Psychology of Aging, 16*(4), 600-614.

Krein, L., Joen, Y.H., Amberber, A.M., & Fethney, J. (2019). The assessment of language and communication in dementia: a synthesis of evidence. *American Journal of Geriatric Psychiatry, 27*(4), 363-377. https://doi.org/10.1016/j.jagp.2018.11.009.

Kroenke, K., Spitzer, R.L., & Williams, J.B. (2001). The PHQ-9: validity of a brief depression severity measure. *Journal of General Internal Medicine, 16*(9), 606-13. https://doi.org/10.1046/j.1525-1497.2001.016009606.x.

de Leon M.J, & Reisberg, B. (1999). *An Atlas of Alzheimer's Disease*. *The Encyclopedia of Visual Medicine Series*. Parthenon Publishing, Carnforth. Available at: http://www.alzinfo.org/clinical-stages-of-alzheimers.

Maestú, F., Peña, J.M., Garcés, P., González, S., Bajo, R., Bagic, A., Cuesta, P., Funke, M., Mäkelä, J.P., Menasalvas, E., Namakura, A., Parkkonen, L., López, M.E., del Pozo, F., Sudre, G., Zamrini, E., Pekkonen, E., Henson, R.N., Becker, J.T. and Magnetoencephalography International Consortium of Alzheimer Disease, (2015). A multicenter study of the early detection of synaptic dysfunction in Mild Cognitive Impairment using Magnetoencephalography-derived functional connectivity. *Neuroimage Clin., 9*, 103-109. doi: 10.1016/j.nicl.2015.07.011Murman, D.L. (2015). The impact of age on cognition. *Seminars in Hearing, 36*(3), 111-121. doi:10.1055/s-0035-1555115.

Nutter-Uphama, K.E., Saykin, A.J., Laura A. Rabin, L.A., Roth, R.M., et al. (2008). Verbal fluency performance in amnestic MCI and older adults with cognitive complaints. *Archives of Clinical Neuropsychology 23*, 229–241. https://doi.org/10.1016/j.acn.2008.01.005.

Obler, L.K., & Pekkala, S. (2008). Language and communication in aging. In B. Stemmer & H.A. Whitaker (Eds.), *Handbook of neurolinguistics* (pp. 351-359). Oxford, UK: Elsevier Press.

Organización Mundial de la Salud (OMS) (2015). Informe mundial sobre el envejecimiento y la salud. http://apps.who.int/iris/bitstream/10665/186466/1/9789240694873_spa.pdf?ua=1.

Paeka, J., & Murrayb, L.L. (2021). Quantitative and Qualitative Analysis of Verb Fluency Performance in Individuals with Probable Alzheimer's Disease and Healthy Older Adults. *American Journal of Speech-Language Pathology, 30,* 481–490. https://doi.org/10.1044/2019_AJSLP-19-00052.

Pascual-Millán, L.F., Martínez-Quiñones, J., Modrego-Pardo, P., Mostacero-Miguel, E., López del Val, L.J., & Morales-Asín, F. (1990). El *set-test* en el diagnóstico de las demencias [The set-test in the diagnosis of dementias]. *Neurología, 5,* 82-85.

Pepe, M.S. (2003). *The statistical evaluation of medical tests for classification and prediction*. New York: Oxford.

Petti, U., Baker, S., & Korhonen, A. (2020). A systematic literature review of automatic Alzheimer's disease detection from speech and language. *Journal of the American Medical Informatics Association*, *27*(11), 1784–1797. https://doi.org/10.1093/JAMIA/OCAA174.

Prince, M., Wimo, A., Guerchet, M., Ali, G.C., Wu Y.T., & Prima M. (2015). World Alzheimer Report 2015. The global impact of dementia an analysis of prevalence, incidence, cost and trends. https://www.alz.co.uk/research/WorldAlzheimerReport2015. pdf. [28.07.2017].

Pulsifer, M.B., Evans C.L., Hom, C., Krinsky-McHale, S.J., Silverman, W. Lai, F. Lott, I. Schupf, N. Wen, J. Rosas, H.D. (2020). Language skills as a predictor of cognitive decline in adults with Down syndrome. *Alzheimer's & dementia: diagnosis, assessment & disease monitoring. 12*(1), e12080. https://DOI: 10.1002/dad2.12080.

Qualls, C. (2005). Neurobiology of normal aging, mild cognitive impairment, and Alzheimer’s disease: A tutorial. *SIG 15 Perspectives on Gerontology, 10*(1), 2–7. https://doi.org/10.1044/gero10.1.

Radanovic, M. & Mansur, L.L. (2011). *Language Disturbances in Adulthood: New Advances from the Neurolinguistics Perspective*. United Arab Emirates: Bentham Science Publishers.

Reisberg, B., Ferris, S.H., de León, M.J., & Crook, T. (1982). The global deterioration scale for assessment of primary degenerative dementia. *American Journal of Psychiatry, 139*, 1136-1139. Doi:10.1176/ajp.139.9.1136.

Rinehardt, E., Eichstaedt, K., Schinka, J.A., Loewenstein, D.A., Mattingly, M., Fils, J. et al. (2014). Verbal Fluency Patterns in Mild Cognitive Impairment and Alzheimer's Disease. *Dementia and Geriatric Cognitive Disorders, 38*(1-2), 1-9. https://doi.org/10.1159/000355558.

Roberts, R. and Knopman, D. S. (2013). Classification and epidemiology of MCI. *Clin. Geriatr. Med., 29*(4), 753-72. doi: 10.1016/j.cger.2013.07.003.

Shafto, M.A., Stamatakis, E.A., Tam, P.P., & Tyler, L. K. (2010). Word retrieval failures in old age: the relationship between structure and function. *Journal of Cognitive Neuroscience, 22,* 1530-1540. DOI: 10.1162/jocn.2009.21321.

Shake, M. C., & Stine-Morrow, E. A. L. (2017). Language and aging. In *Reference Module in Neuroscience and Biobehavioral Psychology*. N.Y.: Elsevier. http://dx.doi.org/10.1016/B978-0-12-809324-5.01889-7.

Small, B. J., Herlitz, A., Fratiglioni, L., Almkvist, O., & Backman, L. (1997). Cognitive predictors of incident Alzheimer’s disease: A prospective longitudinal study. *Neuropsychology, 11*, 413–420. doi:10.1037/0894-4105.11.3.413.

Tsantali, E., Economidis, D., & Tsolaki, M. (2013). Could language deficits really differentiate Mild Cognitive Impairment (MCI) from mild Alzheimer´s disease? *Archives of Gerontology and Geriatrics, 57*(3), 263-270. https://doi.org/10.1016/j.archger.2013.03.011.

Terband, H., Maassen, B., & Maas, E. (2019). A Psycholinguistic Framework for Diagnosis and Treatment Planning of Developmental Speech Disorders. *Folia Phoniatrica et Logopaedica, 71*(5-6):216-227. doi: 10.1159/000499426.

Valle, F., & Cuetos, F. (1995). *EPLA. Evaluación del Procesamiento Lingüístico en la Afasia* [ELPA: Evaluation of Linguistic Processing in Aphasia] Hove, UK: Lawrence Erlbaum.

Voets, N. L., Adcock, J. E., Flitney, D. E., Behrens, T.E.J., Hart, Y., Stacey, R, et al. (2005). Distinct right frontal lobe activation in language processing following left hemisphere injury. *Brain, 129*(3), 754-766. https://doi.org/10.1093/brain/awh679.

Wingfield, A., Aberdeen, J.S., & Stien, E. A. (1991). Word onset gating and linguistic context in spoken word and recognition by young and elderly adults. *The Journals of Gerontology: Psychological Sciences, 46*, 127-129.

Wingfield, A. & Stine, E.A.L. (1991). Expert systems in nature: Spoken language processing and aging. In J.D. Sinnott & J. C. Cavanaugh (Eds.), *Bridging paradigms: Positive cognitive development in adulthood and aging* (pp. 237-258). N.Y.: Praeger.

World Health Organization. (2019). Risk reduction of cognitive decline and dementia: WHO guidelines. Geneva: World Health Organization. Licence: CC BY-NC-SA 3.0 IGO.

Xu, M., López-Sanz, D., Garcés, P., Maestú, F., Li, Q. and Pantazis, D., (2021). A graph Gaussian embedding method for predicting Alzheimer's Disease progression with MEG Brain Networks. *IEEE Trans. Biomed. Eng., 68*(5), 1579-1588. doi: 10.1109/TBME.2021.3049199

Zheng, C., Bouazizi, M., & Ohtsuki, T. (2022). An Evaluation on Information Composition in Dementia Detection Based on Speech. *IEEE Access, 10*, 92294-92306. https://doi: 10.1109/ACCESS.2022.3203068.

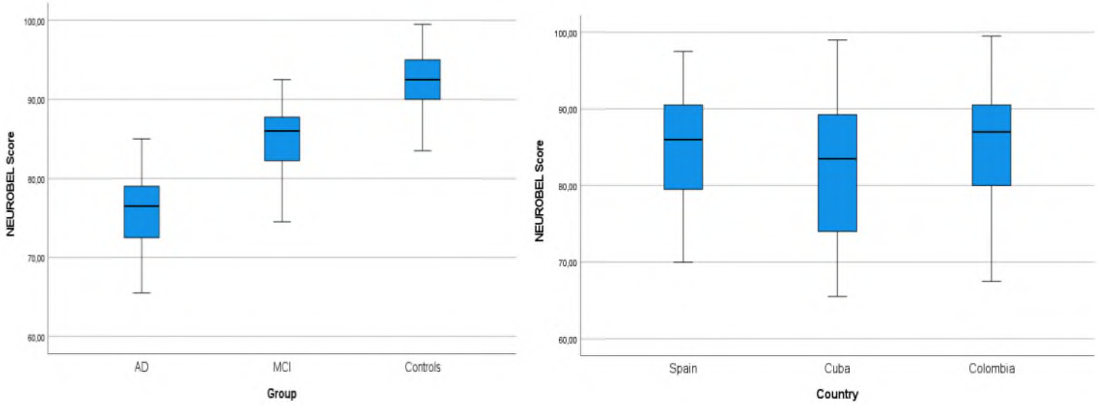


Figure 1. Boxplots representing the distribution and dispersion of the results in the NeuroBel total according to clinical membership group (left) and the country of origin (right). The median, the quartiles (1 and 3) and the extreme values (distance or range of 95% of the cases) are also represented.

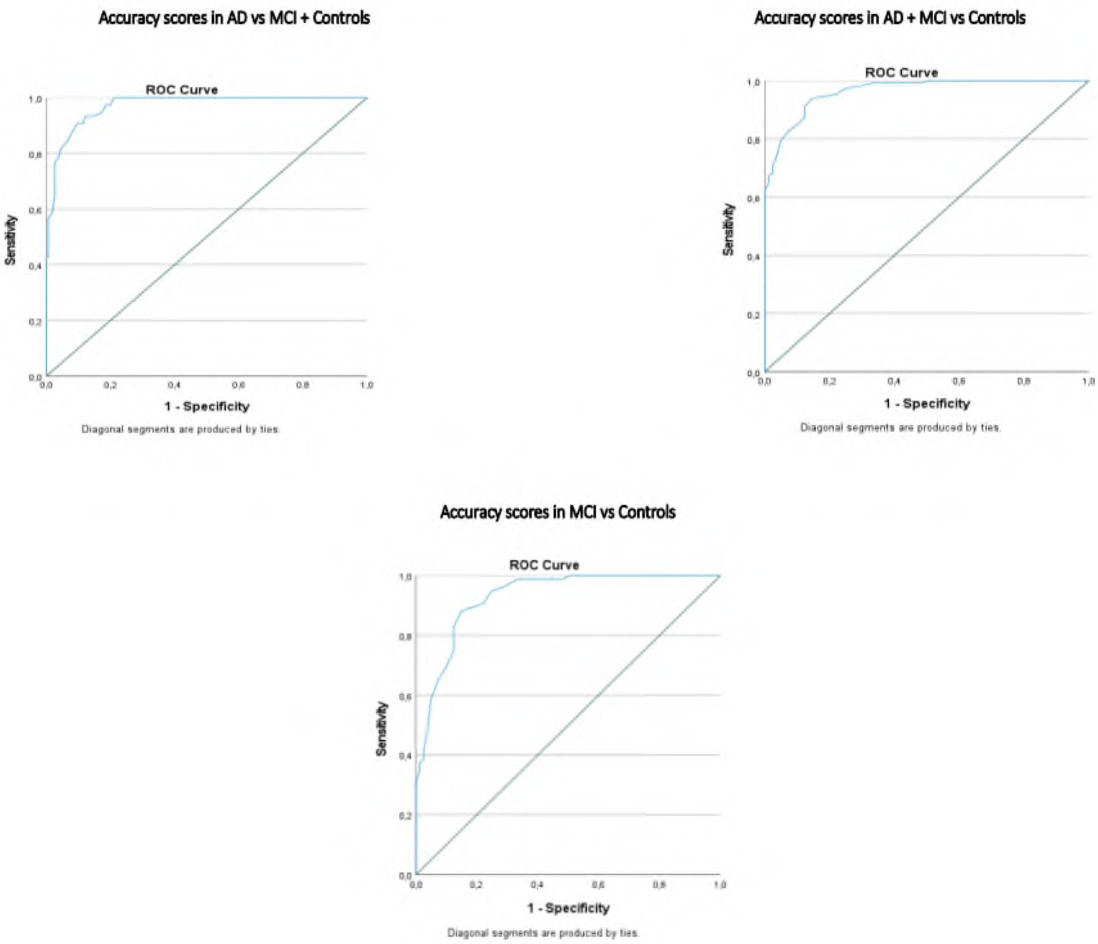


Figure 2. ROC curve accuracy score and the area under the curve (AUC) for NeuroBel showing discrimination between AD and MCI + Controls (left upper panel), between AD + MCI and Controls (right upper panel), and MCI vs Controls (lower panel).

Table 1. **Upper panel**: Demographic data and MMSE scores of the participants, and F and p-values to MCI vs. Controls. **Lower panel**: Demographic data and MMSE scores by country and inter-groups *F* and *p*-values.

	Group						
	AD		**MCI**		**Controls**		***F***	***P***
Gender	52 ♀	24 ♂	56 ♀	19 ♂	62 ♀	19 ♂	.74	.787
Age[a]	78.5 (6.14)		76.0 (7.15)		75.9 (6.85)		.006	.937
Education[a]	7.8 (3.36)		9.4 (4.76)		9.8 (4.61)		.428	.514
MMSE[b]	18.39 (1.85)		23.17 (2.55)		28.25 (1.59)		225.75	<.000

	Country							
	Spain		**Cuba**		**Colombia**		***F***	***P***
Sex	56 ♀	19 ♂	55 ♀	20 ♂	59 ♀	23 ♂	.73	.930
Age[a]	77.3 (5.68)		77.4 (6.62)		75.8 (7.80)		1.42	.244
Education[a]	7.8 (4.28)		10.6 (3.74)		8.7 (4.58)		8.50	<.000
MMSE[b]	23.79 (4.12)		22.80 (4.62)		23.54 (4.81)		.963	.383

Note. Mean values, with standard deviations in round brackets.
[a] In years.
[b] Spanish 30 items version.

Table 2. Means, standard deviation (in parenthesis), inter-subject effects significance, and post hoc comparisons and *p*-values (in parenthesis) for NeuroBel total score and for each task by group membership.

Tasks	**Groups** Mean Score (SD)				**Post-Hoc Comparisons** Mean Differences (*p**)		
	AD	**MCI**	**Controls**	*p**	**AD-MCI**	**AD-Controls**	**MCI-Controls**
Phoneme discrimination	10.43 (1.35)	11.26 (0.95)	11.81 (0.39)	<.001	- .8258 (< .001)	-1.3744 (< .001)	- .5486 (< .001)
Auditory lexical decision	10.62 (1.11)	11.54 (0.50)	11.75 (0.57)	<.001	- .9216 (< .001)	-1.1347 (< .001)	-.2131 (.200)
Spoken word to pict. matching	13.38 (1.64)	14.76 (1.31)	15.46 (0.77)	<.001	-1.3784 (< .001)	-2.0752 (< .001)	- .6968 (.002)
Auditory sentece comprehesion	7.79 (1.63)	8.99 (1.43)	10.23 (1.32)	<.001	-1.1972 (< .001)	-2.4451 (< .001)	-1.2479 (< .001)
Repetition	10.40 (1.00)	11.18 (0.84)	12.84 (0.57)	<.001	- .1952 (.136)	- .6396 (< .001)	- .4444 (< .001)
Object naming	8.78 (1.02)	9.65 (1.03)	10.55 (0.89)	<.001	- .8638 (< .001)	-1.7727 (< .001)	- .9089 (< .001)
Action naming	8.45 (1.56)	9.87 (1.22)	10.86 (0.97)	<.001	- 1.4260 (< .001)	- 2.4107 (< .001)	- .9847 (< .001)
Sentence completion	6.18 (1.95)	7.63 (1.86)	10.33 (1.48)	<.001	- 1.4425 (< .001)	-4.1491 (< .001)	-2.7067 (< .001)
NeuroBel-total	**75.92 (4.53)**	**85.00 (3.61)**	**92.42 (3.67)**	**<.001**			

**p*<.05

Table 3: Discriminant Matrix Structure of NeuroBel tasks (upper panel) and predicted membership classification according to count of *n* and percentage (lower panel)

Predictor Variables	**Function** 1	2
Sentence completion	.546(*)	- .624
Action naming	.444(*)	.180
Object naming	.421(*)	-.107
Auditory sentence comprehension	.406(*)	- .098
Spoken word to picture matching	.378(*)	.327
Auditory lexical decision	.344	.619(*)
Phoneme discrimination	.331	.154
Repetition	.238	- .337

(*) Largest absolute correlation between each variable and any discriminant function.

Classification Results*

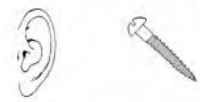
		Group	*Predicted Group Memembership*			*Total*
			AD	MCI	Controls	
Original	***n***	AD	61	15	0	76
		MCI	8	58	9	75
		Controls	0	13	68	81
	%	AD	80.5	19.5	0.0	100.0
		MCI	10.7	77.3	12.0	100.0
		Controls	0	16.0	84.4	100.0

*Correctly classified the 80.6% of the cases from the groups originally selected

APPENDIX A. Contents and structure of NeuroBel screening test

NEUROBEL					
		FUNCTION ASSESSED	**TASK**	**SAMPLE ITEM**	**SCORE out of 100 points**
A. COMPREHENSION	**Phoneme discrimation.**	Auditory discrimination.	-Judge whether a pair of syllables are the same or different. - TOTAL ITEMS: 24; 12 words were same and 12 were different.	*pas.pas* *til-tin* *ken-ken* *pel-pes*	1/2 point by correct answer (max: 12 points)
	Auditory lexical decision.	Auditory word recognition.	Judge which item is a real word and which is a non-word. -TOTAL ITEMS: 24; 12 were words and 12 were non-words.	*nieve* (snow) *rieje* *tornado (*tornado*)* *lorgado*	1/2 point by correct answer (max: 12 points)
	Spoken word to picture matching.	Semantic system and auditory meaning access.	-Testing whether there are difficulties in word comprehension and visual identification. -TOTAL ITEMS: 16	*guitarra, piano, tambor, trompa* *guitar, piano, drum, horn* 	1 point by correct answer (max: 16 points)
	Auditory sentence comprehension.	Syntax comprehension and meaning access.	-Participants must follow simple orders that the neuropsychologist asks to do or answer. -TOTAL ITEMS: 6	- *Señale la ventana y después la puerta* (Point to the window and then the door). – *Dibuje un redondel dentro de un cuadrado* (Draw a circle inside a square).	-Failure: 0 points -Only one order is correct: 1 point -The two orders are correct: 2 points (max: 12 points)

APPENDIX A. Contents and structure of NeuroBel screening test

		FUNCTION ASSESSED	TASK	SAMPLE ITEM	SCORE out of 100 points
	NEUROBEL				
B. PRODUCTIONN	**Repetition.**	Acoustic to Phonological conversion.	- Repetition of words and nonwords - TOTAL ITEMS: 24; 12 were words and 12 were non-words	*barco* (ship) fanto *revolución* (revolution) retionático	1/2 point by correct answer (max: 12 points)
	Object naming.	phonological output lexicon access (nouns).	-Judge naming abilities and anomia. -TOTAL ITEMS: 24; 12 were high frequency-HF (mean=55,5 per million) and 12 were low frequency-LF (mean 3,8 per million).	**HF**-*oreja* (ear) - **LF**-*tornillo*(screw) 	1/2 point by correct answer (max: 12 points)
	Action naming.	phonological output lexicon access (verbs).	-Judge whether there are possible dissociation of action and object naming. -TOTAL ITEMS: 12. 6 were high frequency more than 50 per million (mean=230,3 per million) and 6 were low frequency (mean 22 per million)	*leer*(read)-*bailar*(dance) 	1 point by correct answer (max: 12 points)
	Sentence completion.	morphosyntactic and semantic construction.	-Participants must complete correctly both semantic (according to the context of a picture) and syntactically (from a first word provided by the clinician. -TOTAL ITEMS: 6	*La vela* (candle)… *La vela va a ser encedida por la mujer* (The candle is going to be lit by the woman). 	2 points: sentence correctly completed syntactically and semantically (the participant expresses exactly what happens in the picture) 1 point: sentence correctly completed syntactically, but with semantic errors, either for lack of the most correct word, for not specifying well the scene that appears in the picture or for referring to secondary things on it (i.e., "El cocinero… tiene una zanahoria en la mano/ The cook has a carrot in his hand). 0 points: when the participant fails and there is no answer. If the sentence is incomplete and with grammatical deficits and/or semantically inappropriate because it is not the sense of the picture. When the subject stubbornly begins the sentence with a word that is not the proposal word to begin the sentence (i.e., "El cocinero…y la olla eran llenos"/ untranslatable into English). (max: 12 points)

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APPENDIX B. **List of words accepted to name some objects and actions in the Hispanic America countries that participated in the evaluation with the NeuroBel**

Tasks	Cuba	Colombia
Spoken Word to picture matching	Item 16: banqueta y taburete[1]	
Object naming	Item 3: manzana chiquita[2]	Item 3: cereza y mazacita
	Item 9: botella y pomo	Item 7: peine y peinilla
	Item 10: rana y sapo	Item 10: rana y sapo
	Item 13: banco y banca	Item 13: banco y banca
	Item 14: pimiento y ají	Item 14: pimiento y pimentón
	Item 21: cesta y cesto	Item 21 cesta y cesto
		Item 24: limón y lima
Action naming	Item 6: rezar y orar	Item 6: rezar y orar
	Item 10: conducir y manejar	Item 10: conducir y manejar
	Item 11: esquiar[3]	Item 12: plantar y sembrar[4]
	Item 12: plantar y sembrar[4]	

[1]The word "taburete" (stool) can be confused in Cuba with a rustic chair.
[2]There are no "cerezas" (cherries) in Cuba and the participants used to say "manzana chiquita" (little apple). How ever, the response "Little apple" was not counted as an error, in order not to punish the response.
[3]The picture of "esquiar" (skiinng) in the "Action naming" task causes naming difficulties in Cuba because older people have never seen it. This study did not consider it in the analysis and a statistical correction of the data was made.
[4] In Colombia and Cuba, the action "plantar" (planting) and "sembrar" (sowing) are synonymous in the common use of the population. For this reason, both were considered correct.