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Cross-Cultural Adaptation and Spanish Validation of the Computerized Information Processing Assessment Battery (COGNITO)

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Abstract

Introduction: Mild cognitive impairment (CI) has an exponential increase in its prevalence and causes functional deficits and dependence. Its early detection allows for timely treatment and greater therapeutic efficacy. However, mild cognitive impairment (MCI) is currently underdiagnosed. Although recent decades have seen a rise in computerized instruments for the detection and early diagnosis of MCI, showing numerous advantages over the classic paper-and-pencil methods, such as standardized stimulus presentation. However, their limitations include the use of self-administered application without professional supervision. Few of these instruments have Spanish-adapted versions.
Objective: To translate, adapt, and validate the computerized Information Processing Assessment Battery (COGNITO) battery in the Spanish population and to develop a portable administration system that facilitates its application in different settings. COGNITO was then administered to 232 Spanish participants (18–89 years) without cognitive impairment, after which preliminary normative data were obtained.
Results: Strong positive correlations were found between the main cognitive domains assessed by COGNITO and the variables of age, educational level, and MEC score. The gender variable only correlated with visuospatial skills, with men outperforming women. The test–retest correlations conducted after 4 weeks with 89 participants revealed adequate reliability coefficients ranging between.63 and.66 (visuospatial skills = 0.35). Internal consistency coefficients were satisfactory in Attention-Executive Functions and Memory domains.
Conclusions: The Spanish adaptation of COGNITO shows adequate psychometric characteristics of validity and reliability. The preliminary normative data provided may contribute to the early detection of cognitive impairments associated with both normal aging and various types of neurological pathology. This tool has great utility and versatility for neuropsychological practice.

Keywords: Normative data; Early detection; Test–retest reliability; Computerized assessment; Neuropsychology; Cross-cultural validation

Introduction

In our society, the incidence of cognitive impairment (CI) has increased exponentially in recent years due to an aging population (Miranda et al., 2015; Petersen et al., 2018), increased life expectancy (Cancino & Rehbein, 2016; Roh et al., 2021) and the rise in various neurological diseases such as multiple sclerosis (Korakas & Tsolaki, 2016), cerebrovascular incidents (mainly strokes), head injuries, forms of dementia such as Alzheimer's disease, and tumors (Impact of Neurological Diseases on Spanish Mortality, 2018). CI forms a continuum ranging from non-pathological CI associated with normal physiological aging,

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to more severe stages, such as dementia. The approximate prevalence of MCI is estimated to be around 15–20% in people over 60 years, rising to 14.5–17.6% for those over 65 and up to 22.9% in the 85+ age group. It is predicted that these rates could triple by 2050 (Petersen et al., 2018; Vega et al., 2018). Moreover, CI is observed at increasingly younger ages due to acquired brain damage, suggesting that this population could also benefit from accurate and timely measurement tools.

Cases of persistent CI can cause significant functional impairment of the individual (Garre-Olmo, 2018), reducing their quality of life and that of caregivers by increasing their level of dependence. Deficits in executive functions, especially in problem-solving, error detection, and behavior initiation, have been found to interfere with the level of daily functionality of patients with CI (Overdorp et al., 2016), hence the importance of developing a neuropsychological assessment that allows for identifying these deficits (Montoro-Membila et al., 2021).

There are various CI profiles, some of which are even associated with the same neurological pathology. Thus, we can find patients with impairment in one or multiple cognitive domains, such as memory, attention, and executive functions, resulting in functional impairments of various kinds. This variability is particularly evident in cases of acquired brain damage, where symptoms depend on factors such as the brain areas affected, the type and location of tissue damage, and cognitive reserve. Consequently, there is considerable variability in the degree of cognitive decline observed between patients. Therefore, an early and detailed diagnosis of the CI profile of each patient is essential (Van Den Hurk et al., 2022) to provide more information about the different types of impairment, for administering timely individualized rehabilitation treatment (Domínguez et al., 2021) to reduce its progression, ease some of the socioeconomic costs involved, and improve the quality of life of the patient and their families (Solís, 2014). However, many cases of CI go unidentified (Lee et al., 2019). This underdiagnosis is due to multiple factors, notably the overburdened healthcare system, the short consultation time per patient, the lack of professionals with specific training in CI, the shortage of resources, and the misuse of screening tests as diagnostic tools (Sáez-Zea, 2022).

In the 1980s, following the introduction of the personal computer, CI screening and diagnostic tests and batteries began to be adapted and administered in digitized format (Calderón & Restrepo, 2009; Pico, 2022). In recent years, the development of computerized instruments intended for neuropsychological assessment in the clinical setting has increased significantly due to their numerous advantages over traditional paper-and-pencil methods (Solís, 2014). In Spain, we can note the General Cognitive Assessment Battery (CAB) (CogniFit, 2017), CNS Vital Signs (CNSVS; Gualtieri & Johnson, 2006), Computer-Administered Neuropsychological Screen for Mild Cognitive Impairments (CANS-MCI; Tornatore et al., 2006), Cambridge Neuropsychological Test Automated Battery (CANTAB; Robbins et al., 1994), IntegNeuro Battery (Paul et al., 2005) and the European Cross-Cultural Neuropsychological Test Battery (Nielsen et al., 2019). The key strengths of these instruments include standardization in stimulus presentation, high accuracy in response time measurement and error commission, reduced risk of correction failures and problems attributed to bias or examiner subjectivity, significant cost reduction, and minimization of ceiling and floor effects (Soto-Pérez et al., 2010; Zygouris & Tsolaki, 2014). However, they also present important shortcomings and limitations. These include excessively long administration times, self-administered application without professional supervision, low diagnostic specificity, and automatic report writing of results that are not interpreted by a neuropsychologist with clinical training and experience who can complement the evaluation with other classical neuropsychological tests (Calderón & Restrepo, 2009; Pico, 2022).

The COGNITO Computerized Assessment of Information Processing battery (Ritchie et al., 1993) largely remedies these disadvantages. It is a widely used tool that briefly assesses a variety of cognitive domains (reaction time, working memory, verbal and visuospatial memory, language, and focused and divided attention) using a touch screen device. It is, therefore, a computerized test that can adapt to the level of competence shown by the participant according to their responses to previous items (Olea et al., 2010).

This study aims to translate, cross-culturally adapt, and validate COGNITO to provide preliminary normative and test–retest reliability data in a Spanish population aged 18 to 89. Likewise, we intend to develop a new form of technological administration that facilitates its application in different environments using a portable touch system because the currently available adaptations require a fixed screen—an inaccessible technology that makes its use difficult in contexts such as outpatient clinics, hospitals, or homes. Thus, the creation of a more portable version would allow neuropsychology specialists in our country to have a new instrument available for detailed cognitive assessment applicable from an early age, which could expedite the diagnostic process in clinical practice.

Method

COGNITO battery description

COGNITO has been widely used in the clinical setting for various purposes, such as studying cognitive performance in healthy aging (Artero et al., 2001; Leibovici et al., 1996; Ritchie et al., 2000), monitoring and diagnosing Alzheimer's disease

(Artero et al., 2003; Touchon & Ritchie, 1999; Zamrini et al., 2004), studying the effects of anesthesia on cognitive functioning (Ancelin et al., 2001; Ancelin et al., 2010) and examining CI associated with different psychopathological diseases such as schizophrenia (Capdevielle et al., 2009a; Capdevielle et al., 2009b), and depression (Artero & Ritchie, 2001; Ritchie et al., 1999). In addition to the original French version (Ritchie et al., 1993), the battery has been adapted to other languages and is available in English (Secker et al., 2004) and Indian (Lukose et al., 2018).

COGNITO is a computerized tool that is easily and rapidly administered (approximately 40 min) through a touch screen, which allows accurate quantification of reaction times, correct responses, and types of errors, as well as other qualitative aspects of participant performance such as perseverations, intrusions, and hemineglect of visual fields. The adaptive battery features an initial familiarization task with a tactile device and pre-training trials for each task to facilitate and ensure comprehension. If the participant satisfactorily completes these training trials, the administration of the task will begin from the lowest level of performance, subsequently increasing in complexity. Some tests are automatically discontinued after a set number of failures to avoid discouragement. It evaluates various cognitive domains (attention, information processing speed, language, memory, executive functions, and visuoconstructive skills). In addition, the evaluator has the possibility of selecting difficulty levels, which gives the instrument high diagnostic utility, and its administration does not require high technological skills (Ritchie et al., 1993).

The aforementioned cognitive domains are grouped into four main areas, which are assessed through 25 subtasks. All the scores obtained on the different COGNITO subtests are automatically coded by the program.

Attention and executive functions. COGNITO assesses auditory and visual attention. In the first subtask, "Auditory Attention," the participant is asked to discriminate between long and short sounds. In the second task, "Visual Attention," the participant must select a visual stimulus from a set of distractors. These two subtasks are subsequently performed together to measure focused and divided attention, both of which are involved in working memory. The "Stroop Test" also assesses the ability to allocate attentional resources by inhibiting automatic responses to stimuli.

Memory. This battery evaluates immediate, verbal, and visuospatial long-term memory and implicit learning. Immediate memory is assessed through the subtask "Immediate Recall," in which participants are asked to retrieve a list of proper names beginning with the letters M, J, or G (the choice of these letters corresponds to the highest frequency of proper names in Spanish), previously presented with a retention interval of approximately 30 s, and through the subtask "Visuospatial Span," where it is necessary to recall paths of increasing length on a visual board of squares. In addition, the previously provided names are associated with a series of faces to be recalled later, allowing the assessment of verbal (subtask “Delayed Name Recall”) and visual (subtask "Name-Face Association") long-term memory. Narrative memory is also assessed through two stories that follow a logical temporal sequence (subtask "Narrative Recall") and a non-thematic sequence (subtask "Descriptive Recall"). Finally, the "Implicit Memory" subtask assesses the recognition of previously learned proper names among a set of distractors. Each name is presented individually in a 15-step reconstruction by image pixelation. In the first step, the name is practically illegible; gradually, as the steps progress, the stimuli become sharper. This task is based on the assumption that familiar names will be identified in fewer steps than new distractor names.

Language. COGNITO is able to assess the phonological, morphological, and syntactic linguistic systems. Phonology is assessed using the subtask "Articulation," where the participants are required to read a list of proper nouns to be learned. Morphology is assessed by asking the participant to recognize the meaning of words, which are presented among a set of morphological, phonetic, and semantic distractors (subtask "Phoneme Comprehension"). Syntax is assessed by reading sentences of increasing syntactic complexity and executing a command within a sentence related to an image (subtask “Reading and Syntactic Comprehension”).

This instrument also assesses morphological-lexical ability through the subtask "Naming," which consists of naming common objects, and through the subtasks "Conceptual Associations," "Functional Associations," and "Semantic Associations," in which the participant must select the image that illustrates the use of the previous word, match one object with another from a multiple-choice matrix, and associate an object with another object relevant to a similar semantic category, respectively. In addition, it includes the subtasks “Phonetic Verbal Fluency,” “Semantic Verbal Fluency,” and "Vocabulary" to estimate crystallized intelligence.

Visuospatial skills. COGNITO examines visuospatial skills, a cognitive domain not usually included in other neuropsychological assessment tools. It assesses both visual performance (i.e., the ability to perform goal-oriented tasks within a spatial domain) and visual analysis (perception, location, and high-level ordering of visual material). For example, the first subtask, "Geometric Figure Matching," consists of associating complex shapes in a multiple-choice matrix by matching shapes and lines. The participant must also complete visual sequences based on underlying visual logical understanding (subtask "Matrices") and carry out a construction task that requires assembling components to form a whole by copying two drawings through the subtasks "Abstract Drawing" and "House Drawing.".

Translation process, cross-cultural adaptation, and computerization

To adapt the COGNITO battery to the characteristics of the Spanish culture, the detailed guidelines of the International Test Commission (ITC) Guidelines for Translating and Adapting test (2017) were followed. First, the original scale was translated into Spanish by two independent translators. One of the translations was carried out by an expert translator familiar with the scale's contents, with the aim of providing a clinical perspective, whereas another was made by a translator unfamiliar with the instrument's content. Second, a synthesis process was implemented in which both translations were compared and merged, obtaining a final version after resolving discrepancies by consensus (e.g., terms that do not have a literal translation, ambiguities). Subsequently, following the guidelines developed by Gor-García-Fogeda et al. (2019), a back translation of the battery was performed as a validity check, where the transcribed words and phrases were clarified by two freelance translators familiar with the content of the initial scale. Finally, an expert committee, consisting of Françoise Souchet (founding member and teacher of La Maison de France), Carmen Sáez-Zea, and María Jesús Funes (members of the research team), reviewed all the translations to obtain the final version of the battery, this being a crucial step to ensure adequate cross-cultural adaptation.

It was then necessary to conduct fieldwork in order to cross-culturally adapt four of the subtests included in the COGNITO battery to the characteristics of the Spanish population.

In the subtasks "Articulation" and "Immediate recall," nine proper names (four feminine, five masculine) are used as stimuli. In the original version, they were selected based on two criteria: most frequent names in the French language during the last 50 years whose pronunciation covers the main phonoarticulatory groups: occlusive (Catherine, Colin), constrictive (Janet, Joanne, Joseph, Judith), and nasal (Malcolm, Martin, Michael). During the adaptation process, we selected the most frequent feminine and masculine proper names in Spain in the last five decades. These selections were based on the information provided by the National Institute of Statistics, choosing those that began with the most frequent consonants to cover the required phonoarticulatory groups, which were "M" for the nasal group (María, Marina, Mario, Miguel), "J" for the constrictive group (Jesús, Jorge, Judit), and "G" for the occlusive group (Gabriela, Guillermo).

The same name selection procedure was used for the subtasks "Delayed Name Recall" and "Implicit Memory," choosing the following proper names from each list to act as distracters in the long-term recall of the original nine (Maxime, Pascal, Florence, Maryse, Fabien, François, Patricia, Marie, Florian). In the Spanish adaptation, the equivalents following the same principle were Jessica, José, Juan, Gloria, Gonzalo, Marcos, Martín, Martina, and Mónica.

In the "Phoneme Comprehension" subtest, participants must select the object that previously illustrated a word from a set of morphological, phonetic, and semantic visual distractors. However, when translated into Spanish, the images that acted as phonetic distractors had no equivalence. Therefore, words with the same number of syllables were selected that preferably had a consonant rhyme with the original word so that the phonology between the two would be as accurate as possible (e.g., "copa," "sopa"). The images were then extracted from the platform https://www.soyvisual.org/, an augmentative communication system that uses visual cues to stimulate language development.

Finally, for the computerization of COGNITO, we contacted the research group that created the battery, which provided us with the original source code. Then, we worked on creating the new files necessary for the cross-cultural adaptation of the software to the Spanish version, including multimedia material (e.g., audio, images, and keys) and the translation of the texts and messages appearing on the screen. Once all the necessary material had been developed, it was integrated into the source code to form the software. A computer with a Microsoft Windows operating system remotely connected to a tablet was used so that the software ran on the laptop, although users interacted through a touch device. Compared to the original version (where the need for a dedicated device and a fixed touchscreen monitor made it very difficult to implement), this innovative approach makes the COGNITO battery now a much more versatile, convenient, and user-friendly tool that can be applied in a variety of locations.

Due to the advantages this entails, we subsequently worked successfully on an adapted version of the software executable on any Android device (especially a tablet or Smartphone), with adapted tests that take advantage of the purely tactile interface. This new version includes two integrated modules that facilitate the interpretation of the results and the export of data to a standard format that allows its use on other platforms (e.g., SPSS) needed for subsequent analysis.

Table 1. Sociodemographic characteristics of the sample

Sociodemographic variables	Total (percentage)	Mean	Standard deviation
No. of participants	232		
Age (years)		37.04	17.21
Gender			
Women	145 (62.5%)		
Men	87 (37.5%)		
Level of education			
Primary	21 (9.1%)		
Secondary	36 (15.5%)		
Higher	175 (75.4%)		
MEC score		29.78	0.48

Procedure

We conducted a cross-sectional, correlational, and prospective study in a sample of 232 Caucasian adults, with Spanish as their mother tongue and without CI. Individuals were excluded if they were considered to be suffering from any neurological disorder or sensorimotor impairment that would hinder the application of the visual and auditory COGNITO tests or had been prescribed antiepileptic or antipsychotic treatments that could interfere with neuropsychological performance. Posters and e-mails were used to advertise and distribute the call for participation in the study. Following approval obtained from the Ethics Committee of the Andalusian Biomedical Research Portal PEIBA (Internal code: 1264-M1-22), participants who met the inclusion criteria signed an informed consent form regulated by the current Data Protection Law (New EU Regulation 2016/679 of the European Parliament of last May 25, 2018, and of the Council of April 27, 2016, on Data Protection RGPD).

The neuropsychological assessment was carried out individually, in a single session lasting approximately 1 hr, usually at the home of the participant or the evaluator, in a bright room within a quiet environment without noise or distractions. The second session was conducted after approximately 4 weeks in the same environmental conditions as the first, in order to gather data for assessing test–retest reliability.

The instruments used during the neuropsychological assessment process were the MEC (Lobo et al., 1979) and the COGNITO battery (Ritchie et al., 1993) described earlier. The MEC is screening tool for general cognitive status, adapted to the Spanish population by Lobo et al. (1979). The cut-off point established as indicative of possible CI was raised from 24 to 28 points in this study to decrease the likelihood that any participant would have a cognitive deficit. Information was gathered on a series of sociodemographic variables through an initial questionnaire, which included gender, age, educational level, work status, manual dominance, and current pharmacological treatment.

Three educational levels were established: primary schooling, which includes preschool (2 years) and primary schooling (6 years) for a total of 8 years of formal education; secondary schooling, which includes high school and professional technical education, both from 2 to 4 years, for a final total of 10 to 12 years of education; and higher education, where the participants have more than 10 or 12 years of formal education.

Approximately 4 weeks after the first administration of the battery, 89 of the 232 participants (38.36% of the total sample) agreed to re-take COGNITO to analyze test–retest reliability for each of the tests that make up this instrument. Experimental death occurred due to the inability to contact the participants within the established time frame.

After data collection, statistical analysis was conducted using the IBM SPSS 26.0 program. For each subtask of the battery, means and standard deviations were calculated at both time points, test–retest reliability was evaluated using Pearson's Product–Moment correlation, and learning effects were studied using effect size estimations.

Results

Participants

The sample consisted of 232 adults without CI with Spanish as their first language, aged between 18 and 89 years, with a predominance of women, and adults who had completed higher education. Table 1 details the sociodemographic characteristics of the sample.

Moreover, the variables gender, level of studies, and MEC score were analyzed according to the age of the participants. For this purpose, the sample had previously been divided into age groups, following the original criteria of the authors of the COGNITO battery (Ritchie et al., 1993). The results are presented in Table 2.

Table 2. Gender, educational level, and MEC scores according to age range

Age groups	Number of participants	Gender (Women)	Level of education[1] Mean (SD)	MEC score Mean (SD)
18–29	118 (50.9%)	78 (66.1%)	1.97 (0.16)	9.95 (0.22)
30–39	33 (14.2%)	16 (48.5%)	1.55 (0.62)	29.79 (0.49)
40–49	13 (5.6%)	9 (69.2%)	1.54 (0.78)	29.54 (0.78)
50–59	43 (18.5%)	28 (65.1%)	1.28 (0.77)	29.58 (0.59)
60–69	12 (5.2%)	8 (66.7%)	0.75 (0.87)	29.58 (0.52)
70–79	6 (2.6%)	4 (66.7%)	1.50 (0.84)	29.67 (0.82)
80–89	7 (3.0%)	2 (28.6%)	1.29 (0.95)	29.14 (0.70)

SD=Standard Deviation
[1]The participants' educational level was scored as follows: 0 = Primary, 1 = Secondary, 2 = Higher

A total of seven age groups were established. In all of these, the mean score on the MEC was higher than 29 points, indicating the probable absence of CI. The youngest age group, between 18 and 29, was the most numerous (accounting for 50.9% of the total sample) and had the highest educational level. A predominance of females was also observed in five of the seven established groups.

Preliminary normative data from the cognitive domains of the COGNITO battery

Table 3 shows the scores of the participants on each of the tests that comprise the COGNITO battery, stratified according to the sociodemographic variables of age, educational level, and gender.

Influence of sociodemographic variables

The authors of the original COGNITO categorized the 25 tests that comprise the battery into four cognitive domains: attention and executive functions, memory, language, and visuospatial skills (Table 4) (Ritchie et al., 1993; Ritchie et al., 2014).

Parametric (Pearson) or nonparametric (Spearman) correlations were used depending on the normality of the variables. In addition, a Spearman correlation was conducted to evaluate the influence of the sociodemographic variables of age and educational level on the cognitive domains assessed by the COGNITO battery (Table 5). The results reveal negative and statistically significant correlations between age and attention-executive functions, memory, language, and visuospatial skills, and between educational level and attention-executive functions, memory, language, and visuospatial skills.

To study possible gender differences in the aforementioned cognitive domains, a Student's t-test was used for two independent samples, finding statistically significant differences only in visuospatial skills, with men obtaining a higher mean score than women. No statistically significant differences were found in the other domains (attention-executive functions, memory, and language). These results are shown in Table 6.

Finally, to analyze the relationships between the total MEC score and each the cognitive domains assessed by the COGNITO battery, the Pearson correlation coefficient was also used, yielding positive and statistically significant relationships with all domains, that is, attention, memory, language, and visuospatial skills (See Table 7).

Test–retest reliability

The test–retest reliability analysis was conducted with a sample size of 89 participants, who were retested with the COGNITO battery approximately 4 weeks after the first administration. Table 8 shows the Pearson correlation coefficients obtained for the cognitive domains, which revealed significant correlations between the two applications of the instrument in attention-executive functions, language, and memory, with scores being significantly higher only in the latter domain. However, no correlation was found for visuospatial skills.

Internal consistency

Evaluation of the internal consistency of each cognitive domain revealed satisfactory coefficients for attention and executive functions, questionable results for memory and language, and a poor value for visuospatial skills (Table 9). To further assess the quality of the tests included in the four cognitive domains of COGNITO the "alpha if item deleted" was also calculated. However, no significant changes were observed in these values.

Table 3. Preliminary normative data for the score obtained on each test according to age group, educational level, and gender

COGNITO Test	Age group				Education level			Gender	
	18–29 $N = 118$	30–49 $N = 46$	50–59 $N = 43$	60–89 $N = 25$	Primary $N = 21$	Secondary $N = 36$	Higher $N = 175$	Female $N = 145$	Male $N = 87$
Simple reaction time	12.0(0.0)	12.0(0.0)	10.62(3.68)	10.36(3.9)	10.9(3.25)	10.42(3.94)	11.89(1.09)	11.48(2.31)	11.71(1.73)
Reading and syntactic comprehension	4.56(0.68)	4.28(0.93)	4.3(0.86)	3.68(1.18)	3.81(1.16)	4.14(0.96)	4.47(0.96)	4.3(0.92)	4.46(0.77)
Auditory attention	9.16(1.31)	9.28(1.04)	9.16(1.04)	9.12(1.48)	9.43(0.74)	9.0(1.19)	9.19(1.28)	9.25(1.04)	9.07(1.49)
Visual attention	9.91(0.34)	9.78(0.55)	9.4(0.9)	9.04(1.45)	8.57(1.56)	9.72(0.56)	9.82(0.5)	9.61(0.84)	9.83(0.57)
Auditory and visual attention	9.91(0.37)	9.8(0.45)	9.37(0.95)	8.84(1.95)	8.48(2.06)	9.64(0.68)	9.82(0.52)	9.6(0.91)	9.78(0.85)
Stroop test									
Word	22.13(2.62)	20.67(2.6)	20.28(2.5)	16.16(3.91)	17.43(4.1)	20.17(2.98)	21.4(2.97)	20.8(3.37)	20.93(3.15)
Color	22.62(2.55)	21.15(2.98)	20.98(2.3)	16.68(3.48)	17.38(3.6)	20.5(2.91)	22.04(2.86)	21.35(3.0)	21.43(3.61)
Interference	19.5(2.64)	17.22(3.21)	15.42(4.2)	11.52(4.63)	12.33(4.4)	15.5(3.91)	18.43(3.65)	17.6(3.93)	17.13(4.65)
Articulation and immediate recall	7.9(1.02)	6.91(1.41)	6.6(1.34)	5.36(1.31)	5.48(1.77)	6.44(1.5)	7.55(1.19)	7.27(1.46)	7.05(1.44)
Visuospatial Span	4.18(1.81)	3.59(1.85)	3.42(1.9)	2.6(1.63)	2.05(1.43)	3.31(1.83)	4.05(1.82)	3.64(1.87)	3.93(1.89)
Geometric figure matching	6.27(1.2)	5.83(0.97)	5.93(1.47)	4.84(2.05)	4.48(2.33)	5.61(1.15)	6.22(1.14)	5.89(1.36)	6.09(1.43)
Phoneme comprehension	9.89(0.36)	9.93(0.25)	9.65(0.87)	9.68(0.62)	9.67(0.65)	9.89(0.39)	9.84(0.52)	9.87(0.39)	9.77(0.67)
Name: Associations	9.85(0.4)	9.78(0.41)	9.58(0.58)	9.0(0.86)	9.19(0.98)	9.56(0.65)	9.79(0.43)	9.67(0.61)	9.74(0.49)
Matrixes	18.27(4.05)	15.22(5.1)	13.63(5.42)	11.52(4.94)	9.33(3.12)	12.67(5.25)	17.59(4.39)	15.21(5.49)	17.49(4.4)
Delayed recall of names									
Free recall	7.64(1.24)	6.8(1.61)	6.21(1.65)	4.88(1.98)	5.43(2.31)	6.0(1.91)	7.28(1.44)	7.1(1.67)	6.6(1.8)
Cued recall	7.41(1.39)	6.67(1.57)	6.02(1.68)	4.64(1.93)	5.05(1.83)	5.78(1.79)	7.1(1.58)	6.94(1.67)	6.31(1.89)
Recognition	17.52(0.84)	17.35(1.21)	17.09(1.15)	16.52(1.26)	17.05(1.0)	16.94(1.53)	17.4(0.94)	17.44(0.98)	17.07(1.18)
Name-face association									
Correct names recalled	6.0(2.04)	5.52(2.42)	4.77(2.11)	2.92(2.15)	3.86(2.57)	4.25(2.51)	5.75(2.14)	5.47(2.31)	5.13(2.38)
Correct faces recognized	16.97(1.06)	17.13(1.02)	16.65(1.15)	15.44(1.75)	16.24(1.4)	16.44(1.52)	16.91(1.15)	16.65(1.32)	17.0(1.11)
Semantic verbal fluency	20.74(4.26)	19.65(4.8)	19.67(5.2)	15.16(3.37)	16.9(5.43)	18.42(4.19)	20.33(4.62)	20.34(4.57)	18.7(4.9)
Phonetic verbal fluency	15.94(4.56)	12.78(4.28)	13.86(6.28)	13.72(6.32)	11.48(5.14)	11.44(5.41)	15.74(4.76)	14.13(5.11)	15.6(5.28)
Narrative recall	15.85(5.38)	15.41(4.4)	15.49(4.72)	15.0(4.69)	15.9(4.51)	14.61(4.6)	15.78(5.11)	15.9(5.28)	15.11(4.43)
Descriptive memory	15.0(4.74)	13.91(4.2)	11.72(3.81)	11.92(5.03)	12.67(4.43)	11.64(4.0)	14.4(4.71)	13.99(4.71)	13.6(4.67)
Vocabulary	23.35(4.07)	22.59(4.25)	22.72(5.81)	20.52(6.85)	18.14(5.01)	20.56(5.8)	23.79(4.13)	22.19(4.69)	23.75(5.01)
Implicit memory	6.38(0.85)	6.28(0.91)	6.45(0.75)	7.0(1.07)	6.77(0.93)	6.67(0.92)	6.35(0.86)	6.41(0.89)	6.49(0.89)
Coding									
House	39.61(1.24)	39.63(0.82)	38.81(6.65)	39.16(1.59)	38.86(1.71)	39.44(1.15)	39.48(2.51)	39.62(1.21)	39.42(2.29)
Abstract figure	39.7(0.82)	39.43(1.0)	39.16(1.13)	38.08(2.01)	38.24(1.75)	38.78(1.49)	39.63(0.9)	39.33(1.15)	39.45(1.27)

Values are presented as means (standard deviation)

Table 4. Categorization of the COGNITO test battery into the main cognitive domains assessed

Cognitive domains	COGNITO Test
Attention and Executive Functions	Simple reaction time
	Auditory attention
	Visual attention
	Auditory and visual attention
	Stroop test
	Word
	Color
	Interference
Memory	Articulation and immediate recall
	Visuospatial Span
	Delayed recall of names
	Free recall
	Cued recall
	Recognition
	Name-face association
	Correct names recalled
	Correct faces recognized
	Narrative recall
	Descriptive memory
	Implicit memory
Language	Reading and syntactic comprehension
	Phoneme comprehension
	Name: Associations
	Semantic verbal fluency
	Phonetic verbal fluency
	Vocabulary
Visuospatial Skills	Geometric figure matching
	Matrices
	Coding
	House
	Abstract figure

Table 5. Spearman correlations between each of the cognitive domains and age groups and education level

Correlations			Cognitive domains COGNITO			
			Attention-Executive Functions	Memory	Language	Visuospatial Skills
Spearman's Rho	Age group	r	−0.59**	−0.44**	−0.28**	−0.47**
		N	229	231	231	231
	Education level	r	0.48**	0.35**	0.39**	0.50**
		N	229	231	231	231

* = $p < .05$; ** = $p < .01$; r = Pearson's correlation; N = number of participants

Table 6. Student's t-test for two independent samples: gender differences in cognitive domains

	Female (N = 142)		Male (N = 87)				
	M	SD	M	SD	t	df	p-value
Attention-Executive Functions	99.85	11.38	99.87	11.82	−0.02	227.00	.99
Memory	100.81	13.27	98.29	12.86	1.42	229.00	.16
Language	80.50	11.81	82.01	11.15	−0.96	229.00	.34
Visuospatial Skills	99.92	7.18	102.66	5.85	−3.15	209.42	.00

M = Mean; SD=Standard deviation; t = Student's t-test score; df = degrees of freedom

Table 7. Pearson's correlation coefficient between MEC scores and each of the cognitive domains

Correlations			Cognitive domains COGNITO			
			Attention-Executive Functions	Memory	Language	Visuospatial Skills
Spearman's Rho	Total EQF	*r*	0.467**	0.310**	0.405**	0.492**
		N	229	231	231	231

* = $p < .05$; ** = $p < .01$; r = Pearson's correlation; N = number of participants

Table 8. Test–retest reliability of the domains evaluated by the COGNITO battery

Cognitive domains	Correlation	Confidence interval		Significance
		Lower	Upper	
Attention-Executive Functions	0.65	0.49	0.77	0.01
Memory	0.66	0.49	0.78	0.01
Language	0.63	0.54	0.77	0.04
Visuospatial Skills	0.35	−0.44	0.58	0.20

* = $p < .05$; ** = $p < .01$

Table 9. Cronbach's alpha reliability statistics

Cognitive domains	Cronbach's alpha
Attention-Executive Functions	0.758
Memory	0.675
Language	0.528
Visuospatial Skills	0.424

Discussion

Although classical paper-and-pencil methods have traditionally been used for neuropsychological assessments, recent decades have witnessed a surge in the use of computerized instruments because these have shown considerable advantages in the detection and early diagnosis of CI (Solís, 2014; Soto-Pérez et al., 2010; Zygouris & Tsolaki, 2014). Our research aimed to translate, adapt, and validate the Computerized Assessment of Information Processing COGNITO battery (Ritchie et al., 1993) for the Spanish population.

First, following the International Test Commission Guidelines for Translating and Adapting tests (2017), we completed a process of direct and reverse transcription of the battery to ensure a good validity check (Gor-García-Fogeda et al., 2019). This translation procedure, reviewed by scientists and professionals worldwide, has several editions and has been transcribed into 13 languages, ensuring a high level of linguistic, conceptual, and cultural equivalence between the adapted and original test, as well as better comparability of scores between the two (Hernández et al., 2020; Muñiz et al., 2013). Although the authors of the Indian adaptation of COGNITO followed this same method (Lukose et al., 2018), in the English validation they did not specify the procedure used (Secker et al., 2004).

Fieldwork was also necessary to adapt COGNITO cross-culturally to the characteristics of the Spanish population. Specifically, we sought to find Spanish equivalents for the proper names used in the subtasks "Articulation," "Immediate Recall," "Delayed Recall of Names," and "Implicit Memory". In addition, for the subtest "Phoneme Comprehension," the morphological, phonetic, and semantic translations of the images included were carried out. Similar cultural adaptation procedures were also used in previous versions (Lukose et al., 2018; Secker et al., 2004).

The original battery (Ritchie et al., 1993) was initially designed to assess intellectual functioning in older adults ($N = 335$, 60–100 years). COGNITO was subsequently used in numerous clinical settings (Leibovici et al., 1996; Ritchie et al., 1999; Touchon & Ritchie, 1999; Artero & Ritchie, 2001; Artero et al., 2001; Touchon & Ritchie, 1999; Artero et al., 2003; Zamrini et al., 2004; Capdevielle et al., 2009a; Capdevielle et al., 2009b; Ancelin et al., 2001; Ancelin et al., 2010), but always in populations over 60 years old, and cross-culturally adapted to other populations (Secker et al., 2014; Lukose et al., 2018). However, the battery is potentially applicable from adolescence onwards because it evaluates multiple cognitive domains using traditional neuropsychological tests that have shown to be key for clinical diagnosis of mental disorders also prevalent in younger adults. Additionally, the battery enables the selection of difficulty levels, making it a highly valuable tool for cognitive diagnosis at the earliest ages. For the Spanish validation process, we administered COGNITO to 232 adults, without CI, with Spanish as their first language. Although our sample size was smaller than that used for the original version (Ritchie et al., 1993), the age range was much wider, from 18 to 89 years, with the youngest group being the most numerous (50.9% of the subjects were aged 18–29 years). This has allowed us to see how COGNITO performs at an early age. Furthermore, our sample is highly representative of the general Spanish population given the predominance of women (62.5%) and participants with a high education level (75.4%) (INE, 2021).

Subsequently, we obtained the preliminary normative data of the instrument stratified according to age, educational level, and gender. We further studied the relationship between the main cognitive domains assessed by COGNITO and those sociodemographic variables, observing statistically significant correlations with age and educational level. These correlations are unsurprising given that these variables are significant risk factors for the development of CI (Ciafone et al., 2021; Jongsiriyanyong & Limpawattana, 2018; Pettigrew & Soldan, 2019; Vega et al., 2018). Ritchie et al. (1993) also studied the influence of these variables on COGNITO scores, finding similar results. Concerning gender, higher scores were found for males in the visuospatial tests included in the battery, in line with previous studies showing that males tend to outperform females on these skills from childhood onwards (Barel & Tzischinsky, 2018; McCarrey et al., 2016).

Moreover, a statistically significant correlation was found between COGNITO and MEC scores (Lobo et al., 1979), the Spanish version of the Mini-Mental State Examination (MMSE) (Folstein et al., 1975), one of the most widely used international multidomain screening tools to detect the presence of CI. With a short application time (around 7–10 min) and being translated into more than 50 languages, it is one of the instruments most recommended by the main clinical practice guidelines. Both the original version (Ritchie et al., 1993) and the English validation (Secker et al., 2014) followed the same inclusion criteria which involved exceeding the cut-off point of a brief screening test, the MMSE (Folstein et al., 1975) and the Deterioration Cognitive Observée DECO (Ritchie & Fuhrer, 1992) respectively. However, they did not analyze the relationship between this variable and COGNITO scores.

The test–retest reliability analysis was conducted with 89 participants approximately 4 weeks after the first administration of the battery. Although the sample size is relatively small, it is considered acceptable for test–retest analysis (38.36% of the total). Notably, this sample size is higher than the one used in the English validation study ($N = 36$) (Secker et al., 2004). The test–retest reliability of three out of the four domains evaluated by the COGNITO battery ranged between 0.63 and 0.66, which are considered adequate values. However, we found a test–retest correlation of 0.35 for the visuospatial skills domain. A potential explanation for this finding could lie in the nature of the subtests that constitute this cognitive domain, some of which are more complex and challenging. To further explore this issue, we later conducted an internal consistency analysis of COGNITO, but low values were also obtained in this construct. This result could indicate redundancy or duplication of tests, because the battery has two coding tasks that evaluate drawing copy (House and Abstract figure), so it may be advisable to remove one of the subtests that measure the same construct (Frías-Navarro, 2022). Moreover, direct comparison with previous studies was not possible because neither the original article published by the authors of the battery (Ritchie et al., 1993) or the English validation article (Secker et al., 2004) provided this information. This study is the first to generate internal data for the instrument. Despite the experimental death in this second phase of the research, adequate reliability coefficients that ranged between 0.631 and 0.659 were revealed for three tasks comprising the instrument, and an inadequate value 0.346 in visuospatial skills. Secker et al. (2004) reported significant Pearson's r values ranging from.420 to.900 but only for 16 of the 25 COGNITO subtasks, whereas the original authors of the battery (Ritchie et al., 1993) did not perform this analysis. Therefore, we can confirm that this instrument achieves stable results over time with the exception to the visuospatial skills domain.

Moreover, the researchers had no difficulties in the application, showing that COGNITO is a simple and user-friendly tool. Regarding the rest of the administration characteristics, the battery evaluates a wide variety of cognitive areas commonly affected in CI (attention, reaction time, working memory, verbal and visuospatial memory, language, focused and divided attention, and visuospatial skills) in a relatively short time, which makes it a highly useful instrument in clinical practice, given the short-allocated consultation times resulting from an overburdened health system (Sáez-Zea, 2022). Some computerized neuropsychological assessment batteries validated in Spain, such as the CAB General Cognitive Assessment Battery (CogniFit, 2017), the CNSVS (Gualtieri & Johnson, 2006), and the CANS-MCI (Tornatore et al., 2006) also meet these requirements. In contrast, others have excessively long administration times, even exceeding one hour, as in the case of CANTAB (Robbins et al., 1994) and IntegNeuro (Paul et al., 2005). The CAB (CogniFit, 2017), CNSVS (Gualtieri & Johnson, 2006), and CANS-MCI (Tornatore et al., 2006) batteries are self-administered without any professional supervision, leading to a significant loss of qualitative information. This can pose serious problems because it would be necessary to verify that the person being assessed is who they claim to be (Muñiz et al., 2013). Moreover, the CAB (CogniFit, 2017) and the CNSVS (Gualtieri & Johnson, 2006) have high technological demands, unlike COGNITO, which requires minimal instrumentation, similar to the CANTAB (Robbins et al., 1994) and CANS-MCI (Tornatore et al., 2006) batteries, thus making it a relevant assessment tool. COGNITO is also the only instrument to include training tests that allow for selecting different difficulty levels.

In short, the adapted version of COGNITO meets all expectations, proving to be an excellent tool for the Spanish population. It is an instrument that is easy to apply in various contexts (e.g., medical consultations, hospitals, and homes) because its only technological requirement is to have a touchscreen device. It is also fast, an aspect worth considering due to the lack of time allocated for patient consultations in our healthcare system. Finally, its administration is supervised by experts, which allows for much more complete and truthful information to be obtained in comparison with self-administered tools.

However, like any cognitive assessment tool, we cannot ignore the fact that COGNITO has several limitations. In particular, older adults (over 70 years) were underrepresented in our sample (5.6% of the total), whereas the absence of participants who had completed only primary education in the youngest age group (18 to 29 years) is noteworthy. However, this might be explained by the compulsory nature of secondary education that is currently in force in the Spanish population, which makes it difficult to find individuals who meet this criterion. Finally, it is also worth mentioning the possibility that some participants were unfamiliar with electronic devices, especially those in the older age groups. Nonetheless, technological progress is expected to continue in the coming years, which will inevitably foster the increased adoption of digital devices by older adults (Pico, 2022).

It would be advisable for future research to use increased sample sizes — especially of people over 70 years of age — to shed further light on the normal aging process, the onset of CI, and its early detection and intervention because age is one of the main risk factors for the development of this clinical entity (Cancino & Rehbein, 2016). It would also be useful to recruit younger participants who have completed only primary schooling because their lower education level could have implications for using COGNITO. Likewise, the creation of alternative forms of the battery would be a positive step toward minimizing the possible learning effects derived from its repeated application. It is algo recommended to study the validity, reliability, and sensitivity of the instrument, as well as its diagnostic utility for the early detection of CI in various clinical contexts. Finally, the internal consistency values for the visuospatial skills domain should be reevaluated by considering potential modifications to the original battery structure. In particular, the aim should be to replace certain tests that evaluate this cognitive domain in order to address any issues that may have implications for the future use of the included tasks.

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