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The Mex-Cog cognitive assessment battery: discriminant analysis of the cognitive performance profile in older adults

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Abstract

Objective. To analyze the cognitive profile of a clinical sample using the Mex-Cog cognitive battery and establish which cognitive measures and domains contribute most to group separation. **Materials and methods.** A group of 145 older adults previously diagnosed with dementia (n= 47), mild cognitive impairment MCI (n= 47), or as cognitively normal (n= 51) were assessed with the Mex-Cog cognitive battery. Six linear discriminant analyses (LDA) were estimated to compare dementia vs. cognitively normal, MCI vs. cognitively normal, and MCI vs. dementia, using ten individual measures and six cognitive domains. We used a leave-one-out cross-validation procedure to evaluate the predictive capacity of LDA models. **Results.** Discriminant functions using individual measures and domains distinguished correctly 100% of dementia and cognitively normal groups showing a memory and executive function profile. The predictive group membership for MCI versus cognitively normal varied between 82 and 85%, with a cognitive profile associated with attention-executive function followed by memory. Group separation between MCI and dementia was between 80 and 87%, characterized by orientation, memory, and visuospatial abilities. **Conclusions.** The Mex-Cog cognitive battery is useful for identifying cognitive impairment in older adults.

Keywords: cognitive assessment; dementia; mild cognitive impairment; Mexico

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Batería cognitiva del estudio Mex-Cog: análisis discriminante del perfil de desempeño cognitivo en adultos mayores.
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Resumen

Objetivo. Analizar el perfil cognitivo de una muestra clínica en la batería cognitiva del Mex-Cog y determinar cuáles medidas cognitivas y dominios contribuyen más a separar los grupos. **Material y métodos.** Se aplicó la batería cognitiva a un grupo de 145 adultos mayores previamente diagnosticados con demencia (n= 47), deterioro cognitivo leve (n= 47) y cognitivamente normales (n= 51). Se estimaron seis análisis discriminantes comparando los grupos demencia vs. cognitivamente normales, deterioro cognitivo leve vs. cognitivamente normales, y deterioro cognitivo leve vs. demencia, utilizando diez medidas cognoscitivas y seis dominios. Para determinar la capacidad predictiva de los modelos discriminantes se realizó un análisis de validación cruzada. **Resultados.** Las funciones discriminantes, con las medidas cognoscitivas individuales o los dominios utilizados como predictores, clasificaron correctamente en 100% de los adultos con demencia y cognitivamente normales, observándose un perfil determinado por medidas de memoria y función ejecutiva. La clasificación de los grupos con deterioro cognitivo leve y cognitivamente normal osciló entre 82 y 85% con un perfil cognitivo asociado con medidas de atención-función ejecutiva seguido de medidas de memoria. La separación entre los grupos con deterioro cognitivo leve y demencia estuvo en el rango de 80 a 87%, caracterizado por medidas de orientación, memoria y habilidades visoespaciales. **Conclusiones.** La batería cognitiva del Mex-Cog es útil para identificar el deterioro cognitivo en adultos mayores.

Palabras claves: evaluación cognitiva; demencia; deterioro cognitivo leve; México

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The assessment of cognitive functioning in nationally representative population surveys includes the application of short screening batteries consisting of tests to assess function in cognitive domains, which provide individual cognitive domain scores and a composite score. Despite the limited diagnostic ability of these tests due to their brevity, several efforts to classify individuals into cognitively normal, cognitive impairment no dementia (CIND), and dementia categories have been made, using algorithms that combine information mainly about cognitive and physical functional performance[1] or using self-reported memory.[2-4] These algorithms aim to bring the clinical and statistical models for classifying cognitive function closer. In the clinical model, a practitioner collects information from the patient and their relatives to support the diagnosis of cognitive impairment, whereas in the statistical model, the data analyst operationalizes meaningful clinical information into variables for data analyses.

The international family of studies[5] collaborated with the Harmonized Cognitive Assessment Protocol (HCAP)[6] project to encourage global harmonization in the study of Alzheimer's Disease and Related Dementias (ADRD) and create a more in-depth cognitive assessment of older adults. As a result, the Mexican Health and Aging Study (MHAS)[7] initiated the Cognitive Aging Ancillary Study in Mexico (Mex-Cog) in a sub-sample of the national MHAS wave 2015. The protocol applied a thorough cognitive assessment battery for MHAS participants and a questionnaire for an informed relative or care provider.[8] The first wave of Mex-Cog was completed in 2016, and a second wave of the Mex-Cog was conducted in 2021.

In this paper, we used a clinical sample of individuals who also received the Mex-Cog protocol to investigate differences in their performance with the Mex-Cog cognitive battery across groups clinically diagnosed as dementia, mild cognitive impairment (MCI), or cognitively normal. We also assessed which Mex-Cog measures contributed most to group separation.

Materials and methods

Participants

A sample of 145 older adults diagnosed with dementia (n= 47), MCI (n= 47), or as cognitively normal (n= 51) were selected to receive the Mex-Cog protocol. The sample was selected in collaboration with a group of clinicians (neurologists, geriatricians, and neuropsychologists). Dementia and MCI participants were recruited from the memory clinic at the National Institute of Medical Sciences and Nutrition in Mexico City; cognitively normal participants were recruited from an adult day center also in Mexico City. All participants met five inclusion criteria: 1) aged 55-90 years old; 2) scored below the cut-off point (<5) out of 15 items in the Geriatric Depression Scale;[9] 3) had no visual or auditory limitations that could prevent them from completing the cognitive tasks; 4) had an available informant who spends more than 10 hours per week with them; and 5) accepted to participate in the study and signed the consent form.

Dementia and MCI participants were diagnosed by clinicians following DSM 5[4] criteria for Major and Mild Neurocognitive Disorder based on their clinical history, relative´s report of cognitive and functional abilities, and performance on an in-depth neuropsychological battery. Criteria for cognitively normal classification included lack of cognitive impairment in any cognitive domain (<1 standard deviation below the mean corrected by age and education) based on the Brief Neuropsychological Assessment (Neuropsi in Spanish)[10] and reporting no difficulty in instrumental activities of daily living (IADLs). Based on the diagnosis criteria, clinicians classified participants' cognitive status using the Clinical Dementia Rating Scale (CDR).[11] The full clinical evaluation included the Mini-Mental Status Examination (MMSE) battery (range 0-30)[12] and a history of cardiovascular disease that captured the presence of diabetes, hypertension, stroke, and heart disease (range 0-4), which we present in the descriptive analyses.

Mex-Cog assessment

A gerontologist blind to clinical diagnosis was trained to apply and score the Mex-Cog protocol, following the instructions and instruments used in the Mex-Cog fieldwork. This gerontologist assessed participants with the cognitive battery and interviewed relatives with the informant questionnaire. Paper and pencil tests (copy and recall figures, symbol-digit test, visual scan, and verbal fluency) were scored twice, by the gerontologist and by a member of the Mex-Cog research team. Any discrepancies were resolved by a neuropsychologist. The full Mex-Cog assessment protocol has been described elsewhere.[8] For this paper, we included 31 individual cognitive measures capturing six cognitive domains (table I).

Statistical analysis

We performed descriptive analysis to compare the three groups, using ANOVA for continuous variables and Chi-square for categorical variables. The discriminant analysis determined which cognitive measures and cognitive domains discriminated best between de-

Table I
DESCRIPTION OF COGNITIVE DOMAINS AND COGNITIVE MEASURES

Cognitive domains	*Cognitive measures*
Orientation	*Orientation in time, orientation in place*
Immediate memory*	
Immediate memory approximate	MMSE three-word repetition, CERAD word-list three trials, CSID Short story immediate approximate recall, WMS Long story immediate approximate recall
Immediate memory exact	MMSE three-word repetition, CERAD word-list three trials, CSID Short story immediate exact recall, WMS Long story immediate exact recall
Delayed memory*	
Delayed memory approximate	MMSE three words recall, CERAD word-list recall, CERAD word-list recognition, CSID Short story delayed approximate recall, WMS Long story delayed approximate recall
Delayed memory exact	MMSE three words recall, CERAD word-list recall, CERAD word-list recognition, CSID Short story delayed exact recall, WMS Long story delayed exact recall
Language	MMSE and CSID naming, MMSE and CSID following instructions, MMSE repetition, reading and writing
Visuospatial abilities	MMSE copy pentagons, CERAD constructional praxis, CERAD constructional praxis recall
Attention-executive function‡	Backward counting time, Visual scanning, Semantic Fluency (animals), Serial 3, Serial 7, Symbol-Digit, Similarities, Go-no-Go

* The composite score of Immediate and Delayed memory domains can be estimated considering the total number of ideas recalled in the short and long stories if the ideas are recalled exactly as presented or if the person recalls an approximate idea
‡ The composite score of Attention-Executive Function is estimated considering the coded score of Backward counting and Semantic Fluency (1-4)
MMSE: Mini-mental Status Examination
CERAD: Consortium to Establish a Registry for Alzheimer's Disease
CSID: Congenital Sucrase-Isomaltase Deficiency

mentia, MCI, and cognitively normal groups. To select cognitive measures to include in the linear discriminant analysis (LDA) models, we first conducted an ANOVA with post hoc tests to compare group means, using the 31 individual measures and six cognitive domains. We used F-values, defined as the ratio of the variability *between* groups to the variability *within* groups, from the three pairwise comparisons, selecting the ten individual measures with the highest F-values to include in the LDA models. Next, we conducted six linear discriminant analyses, using each pair of groups as the dependent variable. In the first three LDA models, we included the ten selected individual cognitive measures as predictors; in the second three models, we included all cognitive domains as predictors. Sex, age, and years of education were also included as predictors in all the models. To evaluate the predictive capacity of the LDA models, we used a leave-one-out cross-validation procedure, which successively classified all cases but one to develop a discriminant function and then categorized the case that was left out.[13] We used IBM SPSS Statistics, Version 25.0 (IBM Corp., Armonk, Ny) for statistical analyses.

Ethics statement

The study protocol was approved by the Institutional Ethics Committee (GER-4152-22-18-1) at the *Instituto Nacional de Ciencias Médicas y Nutrición Salvador Zubirán* (INCMNSZ). The study followed the Declaration of Helsinki and Good Clinical Practice guidelines. Written informed consent was obtained from all participants prior to their participation.

Results

Table II presents the demographic and health characteristics of the sample. More than two-thirds of the participants in each group were women, with no differences between groups. Age was significantly higher and educational attainment was significantly lower in the MCI ($p<0.05$) and dementia (<0.001) groups than the cognitively normal group. MCI and dementia participants did not differ significantly in age and education ($p= 0.08$, $p= 0.09$). Table II includes the prevalence of cardiovascular risk factors from

Table II
Demographic and health characteristics of the clinical sample, total and by cognitive function category. Mexico

Characteristics	*Total*	*Normal*	*MCI*	*Dementia*
Total number of cases	145	51	47	47
Sex, n (%)				
Female	98 (67.6)	37 (72.5)	31 (66)	30 (63.8)
Male	47 (32.4)	14 (27.5)	16 (34)	17 (36.2)
Age. mean (SD). years	77.6 (7.3)	73.9 (6.0)	78.2 (6.6)	81.2 (7.3)
Years of education. mean (SD)	11.2 (5.3)	13.6 (4.0)	11 (5.1)	8.7 (5.6)
Cardiovascular risk factors, n (%)				
None	48 (33.1)	25 (49)	13 (27.7)	10 (21.3)
One	58 (40)	18 (35.3)	20 (42.6)	20 (42.6)
Two or more	39 (26.9)	8 (15.7)	14 (29.8)	17 (36.2)
Mean, (SD)	1.01 (0.9)	0.66 (0.7)	1.06 (0.8)	1.34 (1.09)
MMSE, mean score (SD)	24.6 (5.1)	28.3 (1.3)	26.3 (2.5)	18.9 (4.8)

Cardiovascular risk factors: range 0-4 as the sum of diabetes, hypertension, stroke, and heart disease
MMSE: Mini-mental Status Examination (range 0-30); MCI: mild cognitive impairment

diabetes, hypertension, stroke, and heart disease. The number of cardiovascular risk factors was significantly higher among participants with dementia (<0.001) compared to the cognitively normal group. Diabetes and hypertension were highly prevalent among all groups, and the difference was not statistically different (p= 0.073, p= 0.157). Stroke was present in only three dementia and MCI participants; however, the difference between groups was significant (p<0.05) when considering the presence of none, one, and two or more cardiovascular risk factors. The MMSE mean score was significantly lower in the dementia and MCI groups than the cognitively normal group (p<0.001).

Table III presents descriptive results of the cognitive measures and domains in dementia, MCI, and cognitively normal participants. The dementia group had significantly lower scores in all individual cognitive measures and domains (p<0.001) than the cognitively normal group. MCI participants also scored significantly lower than cognitively normal participants in all cognitive domains and individual measures, except the MMSE immediate three words, naming tasks, MMSE repetition, reading and writing, and backward counting (p>0.05). MCI participant scores were significantly higher in all cognitive domains and individual measures, except place orientation, following instructions, and serial 3 (p>0.05).

Dementia vs. cognitively normal classification

Using the individual cognitive measures, the discriminant function to differentiate between dementia and normal participants (table IV, column 1) revealed a significant association between groups and all predictors, accounting for 89.5% of the variation in the grouping variable. In contrast with age, education and sex, which showed loadings below 0.20 in the discriminant function, loadings above 0.40 on all cognitive measures suggest an important discriminatory role. However, delayed long story, 10-word list recall, and constructional praxis recall were the strongest predictors, followed by immediate long story-exact and symbol-digit. Group means of the predictor variables (group centroids) showed a considerable distance between dementia (-3.01) and normal (2.77) classification. The model achieved 100% accuracy in correctly classifying all dementia and normal participants (table Va).

When we used cognitive domains as predictors, the discriminant function accounted for 88.9% of the variation between groups. The delayed memory domain was the predictor with the highest loading, followed by immediate memory, attention-executive function, and visuospatial domains. Orientation had a significant but less important role, while language, age, education,

Table III
COGNITIVE PERFORMANCE BY DEMENTIA, MCI, AND COGNITIVELY NORMAL GROUPS IN THE CLINICAL SAMPLE. MEXICO

Cognitive domains and measures (min-max score)	*Mean (SD)*			*F value*		
	Dementia n= 47	*MCI n= 47*	*Normal n= 51*	*Dementia vs. Norm*	*MCI vs. Normal*	*MCI vs. Dementia*
Orientation (0-9)	4.93	7.32	8.41	143.86‡	24.90‡	41.85‡
	(1.9)	(1.38)	(0.70)			
Orientation time (0-5)	2.31	4.32	4.86	204.59‡	20.57‡	81.29‡
	(1.2)	(0.7)	(0.4)			
Orientation place (0-4)	2.62	3.00	3.55	26.24‡	10.31‡	2.94
	(1.1)	(1.0)	(2.3)			
Immediate memory approximate (0-89)	15.9	26.6	36.74	309.35‡	76.69‡	51.96‡
	(6.2)	(6.0)	(5.4)			
Immediate memory exact (0-89)	12.42	21.1	30.43	316.41‡	76.70‡	50.05‡
	(4.8)	(5.3)	(5.2)			
MMSE 3 words immediate (0-3)	2.60	2.98	3.00	21.82‡	1.09	16.49‡
	(0.6)	(0.1)	(0.0)			
CERAD Word list learning (0-30)	7.40	11.83	16.06	180.17‡	41.93‡	36.28‡
	(3.1)	(3.2)	(3.2)			
Immediate short story approximate (0-6)	2.77	4.36	4.94	70.65‡	7.06*	26.98‡
	(1.0)	(1.2)	(0.9)			
Immediate short story exact (0-6)	1.04	1.83	2.73	72.23‡	20.30‡	14.28‡
	(1.0)	(1.0)	(0.9)			
Immediate long story (0-25)	3.15	7.45	12.75	223.45‡	54.06‡	28.60‡
	(3.1)	(3.9)	(3.2)			
Immediate long story exact (0-25)	1.40	4.49	8.65	225.20‡	55.95‡	31.96‡
	(1.8)	(2.7)	(2.8)			
Delayed memory approximate (0-64)	16.42	29.15	41.59	500.94‡	80.27‡	61.30‡
	(4.8)	(7.5)	(6.2)			
Delayed memory exact (0-64)	14.62	25.02	34.74	491.17‡	73.21‡	63.03‡
	(3.8)	(6.2)	(4.9)			
Delayed short story approximate (0-6)	1.9	3.43	4.47	81.104‡	12.55‡	17.63‡
	(1.6)	(1.7)	(1.2)			
Delayed short story exact (0-6)	0.45	1.30	2.04	80.97‡	11.76‡	19.70‡
	(0.7)	(1.1)	(1.0)			
Delayed long story approximate (0-25)	0.62	4.64	10.80	265.68‡	52.23‡	26.90‡
	(1.4)	(4.4)	(4.0)			
Delayed long story exact (0-25)	0.21	2.64	6.39	179.31‡	40.80‡	23.21‡
	(0.8)	(2.7)	(3.1)			
Delayed CERAD word list (0-10)	0.36	2.66	5.10	259.02‡	44.31‡	49.18‡
	(0.7)	(1.7)	(1.9)			
Recognition CERAD word list (0-20)	13.04	16.72	18.96	204.67‡	35.48‡	41.29‡
	(2.6)	(2.3)	(1.3)			
Delayed MMSE 3 words (0-3)	0.55	1.70	2.25	110.92‡	11.29‡	32.24‡
	(0.9)	(0.9)	(0.6)			
Language (0-14)	11.47	12.53	13.08	26.54‡	6.07*	8.95‡
	(2.0)	(1.3)	(0.8)			

(continues...)

(continuation)

Naming MMSE + CSI-D (0-6)	4.81	5.17	5.31	16.53‡	1.63	7.06‡
	(0.7)	(0.6)	(0.5)			
Instructions MMSE + CSI-D (0-5)	4.17	4.48	4.80	12.98‡	6.15*	3.46
	(1.1)	(0.7)	(0.5)			
Repetition + Reading + Writing MMSE (0-3)	2.50	2.87	2.96	15.50‡	2.00	7.72‡
	(0.8)	(0.4)	(0.2)			
Visuospatial abilities (0-23)	8.17	15.00	19.51	208.31‡	30.09‡	40.75‡
	(4.7)	(4.9)	(3.0)			
Copy figure MMSE (0-1)	0.32	0.8	0.96	79.66‡	7.21‡	23.42‡
	(0.5)	(0.4)	(0.2)			
Copy constructional praxis-CERAD (0-11)	6.83	9.04	10.39	56.56‡	16.44‡	15.16‡
	(3.2)	(2.2)	(0.9)			
Delayed constructional praxis-CERAD (0-11)	1.02	5.17	8.16	238.29‡	24.31‡	44.53‡
	(1.7)	(3.3)	(2.7)			
Attention-executive function (0-164)	35.79	65.34	101.23	216.31‡	67.32‡	33.55‡
	(25.1)	(24.4)	(18.75)			
Backward counting (time in seconds)	23.00	14.34	10.20	12.25‡	1.78	4.70*
	(21.0)	(15.8)	(14.8)			
Visual scanning (0-60)	10.28	21.09	36.06	142.90‡	46.14‡	19.66‡
	(10.2)	(10.7)	(11.0)			
Semantic fluency (animals)	10.68	17.09	21.31	133.79‡	22.44‡	33.26‡
	(6.4)	(4.9)	(3.8)			
Serial 3 (0-5)	3.06	3.62	4.59	23.60‡	12.77‡	2.71
	(2.0)	(1.6)	(0.9)			
Serial 7 (0-5)	1.38	2.51	3.9	69.10‡	19.40‡	9.69‡
	(1.6)	(1.8)	(1.3)			
Symbol-digit (0-56)	9.77	22.04	38.35	215.02‡	64.75‡	24.70‡
	(10.5)	(11.24)	(8.8)			
Similarities (0-3)	1.40	2.09	2.37	30.93‡	4.08*	10.93‡
	(1.0)	(0.8)	(0.6)			
Go-no-Go (0-10)	5.66	8.28	9.29	62.64‡	6.05*	25.30‡
	(2.7)	(2.3)	(1.7)			

* $p<0.05$; ‡ $p<0.001$
MCI: mild cognitive impairment
CERAD: Consortium to Establish a Registry for Alzheimer's Disease
MMSE: mini-mental status examination
CSID: congenital sucrase-isomaltase deficiency

and sex were not loaded on the discriminant function. Groups centroid clearly separated dementia (-2.91) from normal (2.68). The model's accuracy in classifying dementia and normal membership was 100% once again (table Vb).

MCI vs. normal classification

Using the individual cognitive measures, the discriminant function to differentiate between MCI and normal participants (table IV, column 2) revealed a significant association between groups and all predictors, accounting for 62.9% of the variation in the grouping variable. Except for age, education, and sex, all cognitive measures had loadings above 0.30. Variables with the highest loadings were digit-symbol, immediate and delayed long story, visual scanning, 10-word list delayed recall, and verbal learning. The other predictors had weaker loadings. Group centroids substantially separated MCI participants (-1.24) from normal participants (1.34). Cross-validation correctly grouped 83% of MCI participants and 82.4% of normal participants (table Va). The model's accuracy in classifying MCI and normal was 82.7%.

When we used cognitive domains as predictors, the discriminant function accounted for 60.2% of the

variation between groups. The domains with high loadings were immediate and delayed verbal memory and attention-executive function. Visuospatial and orientation domains had a significant but less important role, while language, age, education, and sex were not loaded on the discriminant function. Groups centroid showed a reasonable separation between MCI (-1.27) and normal (1.19) groups. With cross-validation, the model had 84.7% accuracy, correctly classifying 85.1% of MCI participants and 84.3% of normal participants (table Vb).

MCI vs. dementia classification

Using the individual cognitive measures as predictors, the discriminant function to differentiate between MCI and dementia participants (table IV, column 3) revealed a significant association between groups and all predictors, accounting for 66.6% of the variation in the grouping variable. Except for age, education, and sex, all cognitive measures had loadings above 0.30. Predictors with the highest loadings were orientation, 10-word list delayed recall, constructional praxis recall, and 10-word list recognition. The distance between group centroids was -1.39 and 1.39 for dementia and MCI participants. Using cross-validation, the model achieved 81.9% accuracy, correctly classifying 83% of MCI participants and 80.9% of dementia participants (table Va).

When we used cognitive domains as predictors, the discriminant function accounted for 61% of the variation between groups. The delayed memory domain was the predictor with the highest loading, followed by immediate memory, visuospatial, and orientation domains. The attention-executive function domain had a weaker

Table IV
DISCRIMINANT LOADINGS OF INDIVIDUAL COGNITIVE MEASURES AND COGNITIVE DOMAINS IN LINEAR DISCRIMINANT ANALYSIS MODELS BY PAIRS OF COGNITIVE FUNCTION GROUPS. MEXICO

	Function 1 structure coefficients		
	Dementia-normal	*MCI-normal*	*MCI-dementia*
Cognitive measures			
Delayed long story-approximate	**0.570**	**0.567**	0.441
Delayed CERAD word list	**0.563**	**0.523**	**0.613**
Delayed constructional praxis CERAD	**0.540**	0.387	**0.558**
Immediate long story-exact	**0.525**	**0.587**	0.480
Symbol digit	**0.513**	**0.632**	0.403
Recognition CERAD word list	0.500	0.468	**0.529**
Orientation time	0.500	0.353	**0.714**
Learning CERAD word list	0.469	**0.508**	**0.494**
Visual scanning	0.418	**0.533**	0.368
Semantic fluency	0.404	0.372	0.474
Age	-0.191	-0.263	-0.156
Education	0.173	0.223	0.148
Sex	0.032	0.055	0.016
Cognitive domains			
Delayed memory-approximate	**0.810**	**0.744**	**0.811**
Immediate memory-exact	**0.644**	**0.727**	**0.691**
Attention-Executive Function	**0.532**	**0.681**	0.482
Visuospatial abilities	**0.522**	0.455	**0.572**
Orientation	0.434	0.414	**0.571**
Language	0.186	0.205	0.249
Age	-0.197	-0.278	-0.176
Education	0.179	0.236	0.167
Sex	0.033	0.058	0.018

MCI: mild cognitive impairment. Bold fonts on the highest loadings in each discriminant function
CERAD: Consortium to Establish a Registry for Alzheimer's Disease

Table V
Classification results of linear discrimination analysis models using cognitive measures or cognitive domains

	a. Cognitive measures				*b. Cognitive domains*		
	Predicted group membership Total (%)		*Total*		*Predicted group membership Total (%)*		*Total*
	Normal	Dementia			Normal	Dementia	
Normal dementia	51 (100)	0	51	Normal dementia	51 (100)	0	51
	0	47 (100)	47		0	47 (100)	47
	Normal	MCI			Normal	MCI	
Normal MCI	42 (82.4)	9 (17.6)	51	Normal MCI	43 (84.3)	8 (15.7)	51
	8 (17)	39 (83.0)	47		7 (14.9)	40 (85.1)	47
	MCI	Dementia			MCI	Dementia	
MCI dementia	39 (83.0)	8 (17.0)	47	MCI dementia	40 (85.1)	7 (14.9)	47
	9 (19.1)	38 (80.9)	47		6 (12.8)	41 (87.2)	47

MCI: mild cognitive impairment
Total number of correctly predicted individuals, % in parentheses

loading, while language, age, education, and sex were not loaded on the discriminant function. The distance between group centroids was -1.24 and 1.24 for dementia and MCI patients. Using cross-validation, the model achieved 86.2% accuracy, correctly classifying 85.1% of MCI participants and 87.2% of dementia participants (table Vb).

Discussion

We compared the predictive power of the Mex-Cog cognitive assessment battery to categorize a sample of 145 participants who had been clinically classified as normal, MCI, and dementia. We conducted two separate discriminatory analyses, using individual cognitive tasks and the domains they represent as predictors. Overall, the Mex-Cog battery items generally had high accuracy, exhibiting a high percent of correct classification of the clinically classified groups.

The results from the extended battery of neuropsychological tests from the Mex-Cog study showed a general pattern of impairment in all cognitive domains and individual measures, with the lowest scores in dementia participants, followed by MCI participants. As expected, cognitively normal participants had the highest scores. Only place orientation, backward counting, serial 3, and a few individual measures (mainly from the MMSE language and immediate memory tasks) failed to differentiate between MCI and cognitively normal groups and between MCI and dementia groups suggesting this tests have a ceiling effect and lack sensitivity in differentiating between older adults with high educational attainment as those in our sample and who may probably be in the initial stages of MCI and dementia diagnosis.[14] Thus, the profile of cognitive performance from neuropsychological testing allowed us to almost differentiate dementia and MCI participants completely from cognitively normal participants and MCI participants from dementia participants in a sample of Mexican older adults with an average age of 77.6 and 11 years of education.

The discriminant analysis, including individual measures with the highest F-values from the ANOVA analysis, revealed that the discriminant function distinguishing dementia and cognitively normal groups correlated highly with performance in delayed verbal (long story and CERAD word list recall) and visual (constructional praxis recall) memory, followed by immediate memory (long story) and attention-executive function (symbol-digit). The discriminant function correctly classified 100% of our dementia participants. In contrast with the low ceiling effects of the measures which did not differentiated among groups, longer and more complex verbal and visual memory tests, together with timed-tasks of attention and executive function, have demonstrated good to excellent sensitivity and specificity for differentiating dementia patients and cognitively normal individuals.[15] The contribution of non-memory tasks, particularly from executive func-

tions, has been associated with the cognitive profile of older patients with mixed dementia.[16] The cognitive phenotype of mixed Vascular-Alzheimer dementia reveals the coexistence of memory and non-memory impairment.[17-19]

As described in other studies,[15] sensitivity and specificity values to distinguish MCI and cognitively normal groups, are lower when compared to dementia vs. cognitively normal. The discriminant function correctly classified 83% of MCI participants and was highly correlated with attention-executive function and immediate memory measures (symbol digit, visual scan, and long story), followed by delayed verbal memory measures (long story and CERAD word list recall). Attention and executive function tasks that pose higher cognitive demands on the attentional control system and require attention disengagement and refocusing represented manifestations of cognitive decline in MCI participants.[20] Although the clinical diagnosis of MCI participants in our study did not specify which subtypes of MCI were present, predictors loading in the discriminant function (e.g., attention-executive function tasks followed by delayed verbal memory tasks) have been reported to be an expression of incipient stages of Alzheimer's disease; other studies have found high frequency of executive impairment in both amnestic and non-amnestic MCI.[21,22]

The discriminant function differentiating MCI and dementia participants was highly correlated with time orientation and verbal and visuospatial delayed memory (CERAD word list recall and constructional praxis recall), followed by the CERAD recognition task. The discriminant function correctly classified 83% of MCI participants and 80.9% of dementia participants. Other than dementia patients demonstrating more impairment in verbal and visual memory compared to MCI individuals, deficits in orientation and recognition tests have shown to be strong predictors of subsequent cognitive decline in patients transitioning from MCI to dementia.[23,24] This cognitive profile differentiating MCI and dementia participants was predominantly defined by time orientation deficits and global impairment in memory typically associated with AD.[25]

Domain scores calculated by adding individual measures also discriminated well among groups. For dementia versus cognitively normal groups, the highest predictors included memory, attention-executive function, and visuospatial domains. Orientation had a lower loading due to the minor role of place orientation in differentiating cognitive performance between dementia and cognitively normal participants. The profile of MCI participants based on cognitive domains points to a combination of verbal memory and attention-executive function, which corresponded with results using individual measures. The cognitive profile distinguishing MCI and dementia participants included memory, visuospatial, and orientation domains. Language individual measures did not play an important role in differentiating the three groups in univariate analysis. A similar result was present in the discriminant analysis: language was the only domain not loaded in any discriminant function. This finding may be explained by the ceiling effect of language tasks used in the Mex-Cog battery, which were insufficiently difficult to detect language deficits in a sample of highly educated individuals.

Our results also indicate that using a discriminant analysis to classify individuals with dementia, MCI and those cognitively normal according to their cognitive performance, we were able to classify between 80 and 100% of the individuals correctly according to their clinical classification. Variations in the classification rates were minimal when using individual measures or domains as predictors.

Our work has several limitations. First, sample size limited the number of predictors included in the discriminant analysis. Second, the clinical sample was a convenience sample from one city, not representative of the national population of older adults in Mexico. The clinically evaluated participants were part of a highly urban area of Mexico, resulting in a group with higher education than the overall Mexican population of older adults. This trait may also imply that these participants were healthier and more physically functional than the overall population. Due to these limitations, our results may not be generalizable to the population of older adults in Mexico that are represented in the MHAS and the Mex-Cog studies.

Despite these caveats, we offer several implications for our results. First, as a statistical tool, the Mex-Cog battery of cognition assessment appears to be useful to classify participants by cognitive function into cognitively normal, MCI and dementia groups. Second, the rich and detailed Mex-Cog battery may not be needed in its entirety to achieve this goal. A limited number of tasks may offer discriminatory power to study dementia and cognitive aging in population-based studies like the Mex-Cog. Third, users of the Mex-Cog data may opt to use the cognitive domain scores instead of the individual cognitive measures, as the domains appeared to capture well the ability of the numerous items of the battery to distinguish between cognitively normal, MCI, and dementia groups. This would reduce greatly the number of dimensions to represent cognitive function.

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