Montreal Cognitive Assessment

Validation Study for Mild Cognitive Impairment and Alzheimer Disease

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Abstract: The Montreal Cognitive Assessment (MoCA) was recently proposed as a cognitive screening test for milder forms of cognitive impairment, having surpassed the well-known limitations of the Mini-Mental State Examination (MMSE). This study aims to validate the MoCA for screening Mild Cognitive Impairment (MCI) and Alzheimer disease (AD) through an analysis of diagnostic accuracy and the proposal of cut-offs. Patients were classified into 2 clinical groups according to standard criteria: MCI (n = 90) and AD (n = 90). The 2 control groups (C-MCI: n = 90; C-AD: n = 90) consisted of cognitively healthy community dwellers selected to match patients in sex, age, and education. The MoCA showed consistently superior psychometric properties compared with the MMSE, and higher diagnostic accuracy to discriminate between MCI (area under the curve = 0.856; 95% confidence interval, 0.796-0.904) and AD patients (area under the curve = 0.980; 95% confidence interval, 0.947-0.995). At an optimal cut-off of below 22 for MCI and below 17 for AD, the MoCA achieved significantly superior values in comparison with MMSE for sensitivity, specificity, positive predictive value, negative predictive value, and classification accuracy. Furthermore, the MoCA revealed higher sensitivity to cognitive decline in longitudinal monitoring. This study provides robust evidence that the MoCA is a better cognitive tool than the widely used MMSE for the screening and monitoring of MCI and AD in clinical settings.

Key Words: MoCA, neuropsychological test, cognitive screening, Mild Cognitive Impairment, Alzheimer disease

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Cognitive impairment and dementia are the major health issues among older people. Alzheimer disease (AD) is the most common neurodegenerative disorder with a prevalence of 4.4% for those older than 65 years and represents at least 60% of all dementia cases.[1] The serious impact of AD in health care systems worldwide[2,3] and the dramatic projections for the coming years[4,5] stress the need for new effective strategies that are able to slow down or stop the disease progression. It is now generally accepted that prodromal AD is the ideal time window for disease-modifying therapies.

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Mild Cognitive Impairment (MCI) is considered a transitional stage between normal cognitive aging and impaired cognition caused by several pathologies, most frequently AD. This state of continuum is characterized by a deterioration in cognitive functioning greater than expected for the person's age and educational level; however, it does not cause significant functional disability and is insufficient to establish the diagnosis of dementia.[6–9] Longitudinal studies show that these patients progress to overt dementia at a rate of 10% to 15% per year, compared with a rate of 1% to 2% in control subjects.[9] This explains why MCI is now the focus of prediction studies and the target of clinical trials of new disease-modifying therapies.

The early screening of cognitive impairment and its differentiation from age-related decline is thus extremely important. A brief and sensitive cognitive screening tool is indispensable in dealing with this gray boundary area of normality between normal aging, MCI, and mild dementia. The Montreal Cognitive Assessment (MoCA)[10] is a novel international brief cognitive screening tool developed for the detection of MCI and mild AD that may be suitable for this purpose. Previous studies have shown that the MoCA is useful and accurate in identification of milder forms of cognitive impairment, having revealed a high sensitivity in the detection of MCI and AD patients.[11–18] One of the reasons for the good sensitivity of the test is that it allows a more comprehensive assessment of the major cognitive domains, compared with other screening tests. These domains include executive function, short-term memory, language skills, and visuospatial processing. Furthermore, it has been shown that the MoCA's total score is an accurate quantitative estimate of the global cognitive ability in mild and moderate stages.[19,20] Thus, beyond routine screening, the MoCA scores can be used in longitudinal studies as an indicator of the global cognitive decline during progression of the disease.[21]

The aim of the present study was to validate the MoCA[10,22] for cognitive screening of MCI and AD patients. This was carried out by the analysis of its diagnostic accuracy and the by the establishment of optimal cut-off points to detect MCI and AD patients. The data from a longitudinal study with MCI and AD patients have also been analyzed to establish the MoCA's sensitivity for cognitive decline in a short period of time.

METHODS

Design

In the current study, 3 groups of participants were considered: (I) the MCI group; (II) the AD group; and (III) the control group. Patients were recruited from the

Dementia Clinic, Neurology Department of the Coimbra University Hospital (Coimbra University Hospital, Coimbra, Portugal). Control subjects were selected from the database of the MoCA's normative study for the Portuguese population[23] to match patients in sex, age, and educational level. Two subgroups of patients belonging to both clinical groups (MCI and AD) were assessed at a second time point for preliminary longitudinal analysis.

Participants

The total study sample comprised 360 participants distributed between 3 subgroups: (I) the MCI group with 90 patients; (II) the AD group with 90 patients; and (III) the control group with 180 cognitively healthy adults. The demographic data of the participants in each group are provided in Table 1.

To exclude other causes of cognitive decline apart from a degenerative process, all patients were examined by a neurologist (I.S.), and a standard investigation was always carried out, including routine laboratory examinations/analyses (apolipoprotein E genotyping) and imaging studies [structural (computed tomography and/or magnetic resonance imaging) and functional (single-photon emission computed tomography)]. Positron emission tomography and cerebrospinal fluid analysis were carried out more restrictively, although these techniques were considered in younger patients. All patients underwent a battery of comprehensive neuropsychological assessment tests comprising at least the following tools: Mini-Mental State Examination (MMSE) (M. Guerreiro, unpublished doctoral dissertation),[24] Alzheimer Disease Assessment Scale,[25,26] Clinical Dementia Rating scale (CDR),[27,28] Irregular Word Reading Test (TeLPI)[29] for premorbid intelligence estimation, Subjective Memory Complaints scale,[30,31] and Geriatric Depression Scale.[32,33] The MoCA was never used for diagnostic purposes. The diagnosis was established by a multidisciplinary team consensus considering the results of the comprehensive assessment and based on international criteria for MCI of the Petersen workgroup[7] and probable AD.[34,35] The MCI group included patients classified as "amnestic MCI" (single or multidomain)[8] with a classification of 0.5 in the CDR. The AD group included only those patients with mild-to-moderate severity (classified with CDR $\leq$ 2 and MMSE $\geq$ 12 points).

Control group participants were selected, as referred above, from the database of the MoCA's normative study for the Portuguese population.[23] Each patient was matched to a cognitively healthy adult on the basis of variables shown to affect the MoCA's performance (educational level and age)[23] and also on sex, resulting in a perfect match between MCI and associated controls (then designated as the C-MCI group) and between AD and associated controls (C-AD group). Details regarding the controls' recruitment procedure, inclusion and exclusion criteria, and neuropsychological assessment have been described in the previous study.[23]

Procedures

All participants were recruited between September 2008 and July 2010, and each participant was assessed in a single session by an expert in neuropsychology. Only patients with a stable clinical condition (without significant comorbidities), a complete clinical evaluation, and already with a well-established diagnosis, according to the above international criteria, were considered eligible for this study. For each patient considered suitable for the study and at the time of data collection, a diagnosis was recorded by the neurologist in the clinical file. These restrictive criteria imposed the exclusion of 30 patients who were still waiting for data considered essential in the differential diagnosis between AD and other dementias and those whose classification between MCI and AD was not fully established by the multidisciplinary team. In addition, at the outset of this study, the exclusion criteria taken into account in the patients' selection were: higher dementia severity (CDR > 2 and MMSE < 12 points), recent psychiatric comorbidities or therapeutic changes (6 mo before the current neuropsychological evaluation), and significant motor, visual, or auditory deficits, all of which may influence the neuropsychological assessment results.

For the preliminary analysis of the MoCA's sensitivity to global cognitive decline in longitudinal monitoring, we assessed 2 subgroups of patients (35 with MCI and 40 with AD) at a second time point, on average 176.81 ± 67.09 days apart (minimum = 63; maximum = 340).

The present research complied with the ethical guidelines for human experimentation stated in the Declaration of Helsinki and was approved by the Ethics Board of Coimbra University Hospital, by the "Fundação para a Ciência e Tecnologia" (Portuguese Foundation for Science and Technology), and by the Faculty of Psychology and Educational Sciences Scientific Committee. An informed consent was obtained from all the participants after the aims and research procedures were fully explained by a member of the study group. For the AD patient who was incapable of providing consent on his/her behalf, a legal representative provided it.

TABLE 1. Descriptive Statistics for the Sample's Subgroups

	n	Education	Age	Sex	MMSE	MoCA
MCI	90	6.50 ± 4.565	70.52 ± 7.950	55 (61.1)	27.08 ± 2.395	18.31 ± 3.868
C-MCI	90	6.53 ± 4.498	69.59 ± 7.053	55 (61.1)	28.88 ± 1.297	23.64 ± 3.223
AD	90	6.23 ± 4.119	74.22 ± 8.212	52 (57.8)	20.88 ± 4.091	10.06 ± 4.410
C-AD	90	6.24 ± 4.128	73.10 ± 7.539	52 (57.8)	28.09 ± 1.577	22.33 ± 3.471
Clinical group	180	6.37 ± 4.338	72.37 ± 8.270	107 (59.4)	23.98 ± 4.565	14.18 ± 5.851
Control group	180	6.39 ± 4.307	71.34 ± 7.490	107 (59.4)	28.48 ± 1.493	22.99 ± 3.404
Total	360	6.38 ± 4.316	71.86 ± 7.895	214 (59.4)	26.23 ± 4.073	18.59 ± 6.503

Sex is characterized by female's n and respective percentage (%). Data of other variables are presented as mean ± SD.
AD indicates Alzheimer disease; C-AD, subgroup of controls matched with AD patients; clinical group, all patients with MCI and AD; C-MCI, subgroup of controls matched with MCI patients; control group, all controls; MCI, Mild Cognitive Impairment; MMSE, Mini-Mental State Examination (maximum score = 30); MoCA, Montreal Cognitive Assessment (maximum score = 30).

Neuropsychological Testing and Materials

In the clinical interview, the demographic and clinical data were collected through a complete sociodemographic questionnaire and an inventory of past habits, current clinical health status, and medical history. Following this, the same neuropsychologist administered the MMSE (M. Guerreiro, unpublished doctoral dissertation)[24] and the MoCA,[10,22] in that order for all the subjects. The MMSE is a widely recognized and used brief screening tool for cognitive decline; therefore, it is not described in detail here. Both the MMSE and the MoCA are in paper-and-pencil format and are scored out of a possible total score of 30 points, with higher scores indicating better cognitive performance. The MoCA was developed to screen milder forms of cognitive impairment through the assessment of 6 cognitive domains: executive functions; visuospatial abilities; short-term memory; language; attention, concentration, and working memory; and temporal and spatial orientation.[10] It is composed of a 1-page test, with an application time of approximately 10 to 15 minutes, and of a manual in which explicit instructions on its administration and scoring system are available. The cultural adaptation process of the MoCA for the Portuguese population involved the translation, retroversion, and linguistic improvement of the tool and of the administration and scoring instruction manual, studies with the MoCA's Portuguese experimental version, the revision and adjustments required to finalize the MoCA's Portuguese final version, and an analysis of the equivalence between the original and the Portuguese final version, as described by Freitas et al.[36] In the current study, the MoCA's total score refers to the raw score without correction point for education effects, considered in the original study,[10] because this correction is not used in the Portuguese population.[23]

Statistical Analysis

Statistical analyses were carried out using the Statistical Package for the Social Sciences (version 19.0, IBM SPSS, Chicago, IL). Descriptive statistics were used for the samples' characterization, and the χ^2 test and the 2-sample t test allowed comparisons between the groups. Cronbach α was considered as an index of internal consistency. To assess test-retest reliability, intraclass correlation coefficients between scores at baseline and at follow-up after 3 and 18 months for the control patients were calculated. Interrater reliability was calculated using the Pearson correlation coefficient between the scoring of 2 independent evaluators. The convergent validity was determined using Pearson correlation coefficients between the MoCA scores and MMSE scores. The group differences were examined using the 2-sample t test and analysis of covariance. The preliminary data of the longitudinal study were analyzed using a paired-sample t test.

The diagnostic accuracy of the MoCA and the MMSE for the prediction of the clinical diagnosis of MCI and AD was assessed through the receiver operating characteristics (ROC) curve analysis implemented in MedCalc (version 11.6, MedCalc Software, Mariakerke). In this analysis, the areas under the curve (AUC) can vary between 0.5 and 1, with larger AUC indicating better diagnostic accuracy. The ROC curves were compared according to the AUC comparison method of Hanley and McNeil.[37] The optimal cut-off points for each screening instrument that yielded the highest Youden index were selected, with higher Youden index indicating maximization of the sensibility and specificity. For the analysis of the predictive value of these tests, we calculated, for each cut-off point, the sensitivity (the probability for subjects with cognitive impairment to have a positive test), specificity (the probability for subjects without cognitive impairment to have a negative test), positive predictive value (PPV, the probability of disease in subjects who have a positive test), negative predictive value (NPV, probability of the classification "lack of disease" in subjects who have a negative test), and classification accuracy (probability of correct classification of subjects with or without cognitive impairment).

RESULTS

Sample Characterization

Characteristics of the study sample, and in more detail of all the subgroups, are provided in Table 1. For this description, we considered the following variables: sample size, educational level, age, sex, MMSE score, and MoCA score.

As mentioned above, the control participants were selected from the database of MoCA's normative study for the Portuguese population[23] to match the educational level, age, and sex of patients of the clinical groups. No statistically significant differences were found in educational level [$t(178) = 0.049$, $P = 0.961$], age [$t(178) = 0.833$, $P = 0.406$], and sex [$\chi^2(1) = 0.000$, $P = 1.0$] between the MCI and C-MCI groups. Similarly, the AD and C-AD groups did not differ in educational level [$t(178) = 0.018$, $P = 0.986$], age [$t(178) = 0.955$, $P = 0.341$], and sex [$\chi^2(1) = 0.000$, $P = 1.0$]. The MCI group and the AD group did not differ in educational level [$t(178) = 0.411$, $P = 0.681$] and sex [$\chi^2(1) = 0.092$, $P = 0.761$]; however, the AD patients were significantly older than MCI patients [$t(178) = 3.071$, $P = 0.002$], because of which the average onset of symptoms of MCI precedes the onset of AD.

Psychometric Properties

Cronbach α of the MoCA as an index of internal consistency was 0.903 for the total study sample, and the respective value for the MMSE was 0.856. Regarding the analysis carried out to determine which of the MoCA items could be eliminated to increase consistency, the results indicate that none should be excluded. Cronbach α values for the subgroups are provided in Table 2. The test-retest reliability was measured through the intraclass correlation coefficient between baseline and follow-up data. This analysis was carried out only for the subsample of the control group in 2 follow-up settings: 3 months (n = 30; on average 146.87 ± 42.937 d apart; minimum = 68 d and maximum = 200 d) and 18 months (n = 30; on average 515.04 ± 154.195 d apart; minimum = 101 d and maximum = 676 d). The obtained MoCA values were, respectively, 0.909 and 0.877 and the corresponding values for MMSE were, respectively, 0.755 and 0.665 (Table 2). Interrater reliability data were collected from a subsample of 60 tested participants of all groups, and the obtained intraclass correlation index for the MoCA was 0.988. Another observation was that MoCA scores were highly and positively associated with MMSE scores (total study sample, $r = 0.849$, $P < 0.001$), which is indicative of convergent validity. The correlation values for the subgroups are presented in Table 2.

Group Differences

When analyzing the total sample, the MoCA scores were lower in the AD group than in all other groups and were lower

TABLE 2. Psychometric Properties

	Internal Consistency		Reliability			
	Cronbach α		Test-Retest			Convergent Validity
	MoCA	MMSE	MoCA	MMSE	Interrater	Correlations MoCA/MMSE
MCI (n = 90)	0.723	0.617	3 mo: 0.909	3 mo: 0.755	0.988	0.601
AD (n = 90)	0.824	0.771	18 mo: 0.877	18 mo: 0.665		0.700
C-MCI (n = 90)	0.648	0.457				0.637
C-AD (n = 90)	0.677	0.402				0.600
Total (n = 360)	0.903	0.856				0.849

Correlation values at a significant level, $P < 0.01$.
AD indicates Alzheimer disease; C-AD, subgroup of controls matched with AD patients; C-MCI, subgroup of controls matched with MCI patients; MCI, Mild Cognitive Impairment; MMSE, Mini-Mental State Examination (maximum score = 30); MoCA, Montreal Cognitive Assessment (maximum score = 30).

in the MCI group than in both control groups. The MoCA scores did not differ between the control groups [$t(178) = 2.626$, $P = 0.225$] (Table 1). Furthermore, we can observe that there were statistically significant differences when MoCA scores were compared between MCI and C-MCI groups [$t(178) = 10.050$, $P < 0.001$, mean difference = 5.333 ± 0.531] and between AD and C-AD groups [$t(178) = 20.756$, $P < 0.001$, mean difference = 12.278 ± 0.592]. Because AD patients were significantly older than MCI patients, the analysis of differences in scores between clinical groups was carried out using an analysis of covariance to control for the effects of age. It can be observed that the differences between MCI and AD patients' scores [$F(1177) = 160.052$, $P < 0.001$, $\eta^2 = 0.48$, mean difference = 7.930 ± 0.627] were in fact significant. The corresponding values for the MMSE were as follows: (I) the MCI and C-MCI group: $t(178) = 6.270$, $P < 0.001$, mean difference = 1.800 ± 0.287; (II) the AD and C-AD group: $t(178) = 15.603$, $P < 0.001$, mean difference = 7.211 ± 0.462; and (III) the MCI and AD group: $F(1177) = 146.899$, $P < 0.001$, $\eta^2 = 0.45$, mean difference = 6.231 ± 0.514. These results indicate that, although the differences in the MMSE scores are statistically significant, the score differences obtained with the MoCA are more pronounced. A more detailed analysis reveals that there were statistically significant differences in all cognitive domains of the MoCA in the 3 comparisons: (I) the MCI and C-MCI group; (II) the AD and C-AD group; and (III) the MCI and AD group. Table 3 summarizes the results.

Cut-off Points

The ROC curve analysis was carried out and the predictive values were determined to evaluate the diagnostic accuracy of MoCA to discriminate MCI and AD patients from cognitively healthy adults. Graphic representations of the ROC curves are provided in Figure 1.

It can be observed that both ROC curves that were referred to the MoCA fully include the curve for the MMSE, which is a clear indication that there is always a cut-off for the MoCA with higher sensitivity and specificity for any cut-off chosen for the MMSE. The discriminant potential of the MoCA for MCI was high, with an AUC of 0.856 [95% confidence interval (CI), 0.796-0.904], and that for AD was excellent, with an AUC of 0.980 (95% CI, 0.947-0.995). In contrast, corresponding values for MMSE were 0.745 (95% CI, 0.674-0.807) and 0.957 (95% CI, 0.916-0.981). The AUCs for MCI are significantly different ($z = 3.372$, $P = 0.0007$), according to the AUC comparison method of Hanley and McNeil,[36] indicating different classification accuracies of the tools for milder cognitive impairment. No statistically significant differences were found between the AUCs for AD ($z = 1.636$, $P = 0.1018$). The optimal cut-off point for maximum accuracy (Youden index) and the respective values of sensitivity, specificity, PPV, NPV, and classification accuracy are described in Table 4.

The cut-off point of below 22 yielded the greatest Youden index for the MoCA in discrimination between MCI and controls. With this cut-off point, MoCA had a good sensitivity (81%), specificity (77%), PPV (78%), NPV (80%), and classification accuracy (80%), and all these values were significantly superior compared with the respective values for the MMSE. Furthermore, with respect to the capacity of discrimination between AD patients and controls, once again the MoCA demonstrated excellent sensitivity (88%), specificity (98%), PPV (98%), NPV (89%), and classification accuracy (93%) at the optimal

TABLE 3. Group Differences in Cognitive Domains of the MoCA

Cognitive Domains	MCI and C-MCI	AD and C-AD	MCI and AD
Executive functions	$t(178) = 4.975$, $P < 0.001$	$t(178) = 9.766$, $P < 0.001$	$t(178) = 7.073$, $P < 0.001$
Visuospatial skills	$t(178) = 5.564$, $P < 0.001$	$t(178) = 9.616$, $P < 0.001$	$t(178) = 7.006$, $P < 0.001$
Short-term memory	$t(178) = 9.773$, $P < 0.001$	$t(178) = 20.732$, $P < 0.001$	$t(178) = 6.581$, $P < 0.001$
Language	$t(178) = 2.964$, $P = 0.003$	$t(178) = 8.800$, $P < 0.001$	$t(178) = 7.010$, $P < 0.001$
Attention, concentration, and working memory	$t(178) = 5.199$, $P < 0.001$	$t(178) = 11.123$, $P < 0.001$	$t(178) = 7.217$, $P < 0.001$
Temporal and spatial orientation	$t(178) = 2.974$, $P = 0.003$	$t(178) = 13.886$, $P < 0.001$	$t(178) = 12.038$, $P < 0.001$

AD indicates Alzheimer disease; C-AD, subgroup of controls matched with AD patients; C-MCI, subgroup of controls matched with MCI patients; MCI, Mild Cognitive Impairment.

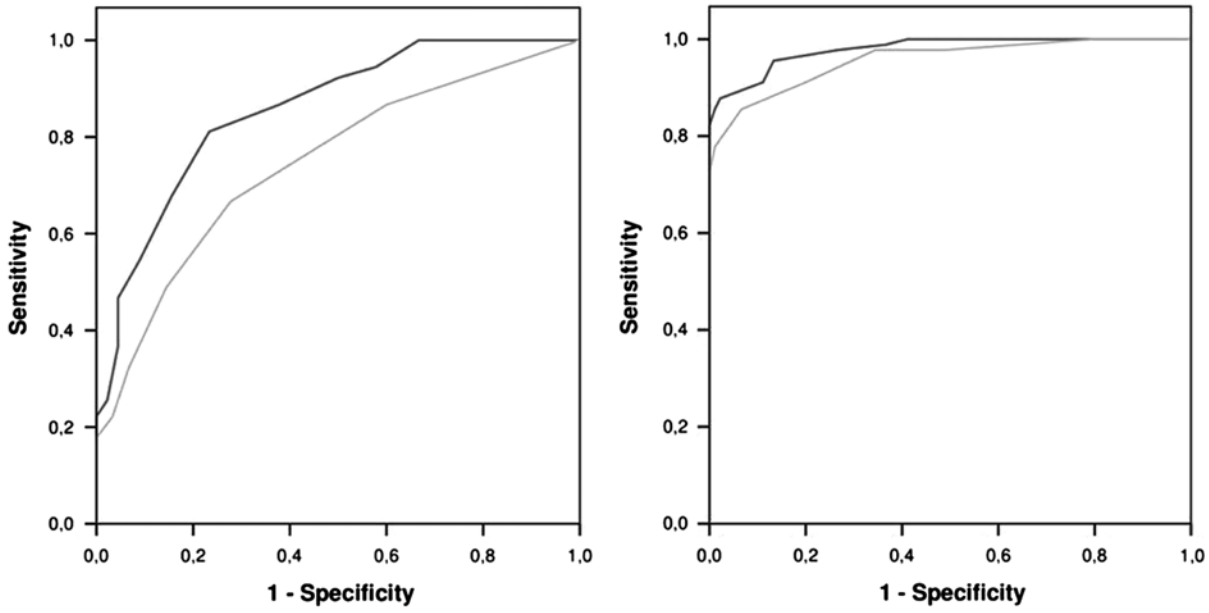

FIGURE 1. ROC curve analysis of the MoCA (dark gray) and MMSE (medium gray) to detect MCI (left) and AD (right). AD indicates Alzheimer disease; MCI, Mild Cognitive Impairment; MMSE, Mini-Mental State Examination; MoCA, Montreal Cognitive Assessment; ROC, receiver operating characteristics.

cut-off of below 17 points, and again all these values were more favorable than the respective values for the MMSE.

Preliminary Analysis of the Longitudinal Study

For the preliminary analysis of the MoCA's sensitivity to global cognitive decline during longitudinal monitoring, 2 clinical subgroups of patients (35 with MCI and 40 with AD) were assessed at a second time point, on average 176.81 ± 67.09 days apart (minimum = 63; maximum = 340). When considering all patients (n = 75), statistically significant differences in MoCA scores were observed between both assessments [$t(74) = 4.278$, $P < 0.001$], in contrast to what was found with the MMSE [$t(74) = 1.871$, $P = 065$]. A similar analysis for each clinical subgroup showed statistically significant differences on MoCA scores for both MCI [$t(34) = 2.612$, $P = 0.014$] and AD patients [$t(39) = 0.5651$, $P < 0.001$]. An equivalent analysis using the MMSE revealed that the differences were significant for the AD group [$t(39) = 2.824$, $P = 0.008$], whereas for MCI the MMSE showed no sensitivity to cognitive decline [$t(34) = 1.873$, $P = 0.070$]. A more detailed and parceled analysis of the cognitive domains of the MoCA also revealed interesting results. When considering the total sample, the differences between the 2 evaluations were significant for visuospatial skills [$t(74) = 2.487$, $P = 0.015$]; short-term memory [$t(74) = 2.669$, $P = 0.009$]; attention, concentration, and working memory [$t(74) = 2.213$, $P = 0.030$]; and temporal and spatial orientation [$t(74) = 4.449$, $P < 0.001$]; the differences were without significance for language and executive functions. When considering the clinical subgroups, an isolated significant difference was found for MCI patients in the short-term memory domain [$t(34) = 2.390$, $P = 0.023$], whereas the same analysis for the AD subgroup revealed statistical significance for attention, concentration, and working memory [$t(39) = 2.071$, $P = 0.045$] and also for orientation [$t(39) = 5.244$, $P < 0.001$].

DISCUSSION

The main objective of this study was to validate the MoCA as a cognitive screening tool for MCI and AD. The results confirm its tremendous potential and provide robust evidence that the MoCA is a better tool for this purpose in

TABLE 4. Diagnostic Classification Accuracy

	Cut-off	AUC	Sensitivity	Specificity	PPV	NPV	Classification Accuracy
MCI							
MoCA	< 22	0.856	81	77	78	80	80
MMSE	< 29	0.745	67	72	71	48	69
AD							
MoCA	< 17	0.980	88	98	98	89	93
MMSE	< 26	0.957	85	93	93	87	89

Sensitivity, specificity, PPV, NPV, and classification accuracy values were expressed in percentage.

Cut-off values indicate the minimum score required for absence of signal.

AD indicates Alzheimer disease; AUC, area under the operating characteristic curve; MCI, Mild Cognitive Impairment; MMSE, Mini-Mental State Examination (maximum score = 30); MoCA, Montreal Cognitive Assessment (maximum score = 30); NPV, negative predictive value; PPV, positive predictive value.

comparison with the widely used MMSE. In fact, it was verified that the correlation coefficient between the 2 cognitive screening tools was moderate to good, suggesting convergent validity. Nevertheless, the psychometric properties of the MoCA examined both in the total sample and in each subgroup showed good properties and were revealed to be consistently superior to those of the MMSE. As was discussed previously, we believe that the 2 main reasons for the higher results of the MoCA at this level were as follows: first, the inclusion of the executive function assessment; and second, the consideration of more complex tasks to measure short-term memory, language, attention, concentration, working memory, and visuospatial skills.

Moreover, the analysis of group differences indicates that both instruments are able to distinguish between the clinical and control groups. However, the differences between the groups were much more pronounced when the MoCA was used, in comparison with the MMSE, which is reflected in the consistently higher mean differences of the MoCA. Furthermore, we observed statistically significant differences in all cognitive domains of the MoCA and in all group comparisons. These results confirm the higher capacity of the MoCA to discriminate between normal aging and pathologic cognitive decline, as well as between MCI and dementia.

The ROC curve analysis of the MoCA compared with the MMSE also showed that the MoCA exhibits a better diagnostic accuracy to discriminate MCI and AD patients from cognitively healthy adults. In our sample, the ideal cut-off point reached was lower than the original cut-off of 26 proposed by the authors,[10] as in other published results.[14,15,17,18] We observed that at an optimal cut-off point below 22 for MCI, the MoCA had values significantly superior to the MMSE for sensitivity (81%), specificity (77%), PPV (78%), NPV (80%), and classification accuracy (80%). With an optimal cut-off of below 17 points for AD, the MoCA once again showed better results than the MMSE on sensitivity (88%), specificity (98%), PPV (98%), NPV (89%), and classification accuracy (93%). These results confirm that the MoCA is a better cognitive screening tool for the detection of MCI and AD conditions compared with the MMSE, showing overall superior discrimination validity. The capacity of the MoCA to identify different severity levels of cognitive decline justifies the pertinence of considering different cut-off points for MCI and dementia. This approach seems to be more useful and informative than a single cut-off point for cognitive decline as suggested in other studies, particularly in the original work of Nasreddine et al.[10]

An additional observation based on the present study regards the extremely poor diagnostic accuracy of the MMSE to identify MCI, which is reflected in overall low results, mainly in poor sensitivity (67%), classification accuracy (69%), and very poor NPV (48%). This is a clear indication that, whenever the MMSE is used to screen for milder forms of cognitive decline, the probability of false-negative cases is very high. This is especially critical because of the current emphasis placed upon the early detection of cognitive impairment. Nevertheless, the MMSE remains the most commonly used screening tool despite the widely referred limitations in the literature. Our results are a clear argument in favor of these opinions.

Finally, considering our analysis of the sensitivity of the MoCA to cognitive decline in patients that were monitored longitudinally, we could demonstrate evidence of decline in a short period of time. Furthermore, beyond its capacity to quantify cognitive decline, the MoCA also provides comprehensive information on the differential profile of clinical deterioration in MCI and AD.

We believe that the added value of the present study is the rigorous methodology used. It included the following: (I) well-validated study samples (patients with misclassification and more advanced dementia were excluded, both characteristics capable of compromising the analysis of the discriminant capacity of the tools); (II) homogeneity of the clinical groups; (III) a control sample with subjects recruited from the community and well-characterized as cognitively healthy adults; (IV) equivalent sample sizes (which reduces the possible biases of sample sizes in statistical analysis); (V) perfect matching between groups regarding sociodemographic characteristics that have a significant influence on the performance of MoCA; and (VI) rigorous application of MoCA with no interrater variability (all participants were assessed by the same experienced neuropsychologist).

However, some limitations of the current study must be addressed. First of all, because only the amnestic subtype of MCI (single or multidomain) was considered, the generalization of the results to other forms of MCI should be done cautiously. Similarly, although the Portuguese final version of the MoCA resulted in a rigorous process that followed the methodological guidelines for cultural adaptation studies, and the maximum equivalence between the original tool and the Portuguese final version of MoCA was pursued,[36] the generalization of these results to other target populations should be done cautiously. In contrast, the present study compares people with a clear diagnosis of AD/MCI with healthy people who do not present health and cognitive difficulties, like the majority of the clinical validation studies of screening tools. However, in the context of clinical applicability of a cognitive screening tool, such as the MoCA, the most common diagnostic challenge is to identify clinical conditions among people with complaints of memory impairment or other cognitive difficulties or psychological disorders. Hence, we believe that such a question represents a very interesting challenge with a clear practical utility that should be a part of future efforts within this field of research. Finally, despite being a promising tool, the results of the preliminary analysis of the longitudinal evaluation require the corroboration by an ongoing study with longer follow-up and more robust samples.

In conclusion, this study produced considerable evidence of the overall superiority of the MoCA in comparison with the MMSE as a global cognitive assessment tool with respect to discriminant validity and diagnostic accuracy. This was confirmed by the identification of MCI and AD and by the discrimination between both forms of cognitive decline and normal cognitive aging. Furthermore, the results suggest that the MoCA is sensitive to cognitive decline in a short period of time and may capture profiles of cognitive deterioration along the evolution of the disease. Thus, this study shows a clear advantage in the use of the MoCA compared with the use of the MMSE and brings together arguments for the use of the MoCA as a reliable brief cognitive tool, which should be recommended both for screening and follow-up in primary clinical setting and geriatric health care.

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