J Neurol (2010) 257:728–734
DOI 10.1007/s00415-009-5399-5

ORIGINAL COMMUNICATION

Validation studies of the Portuguese experimental version of the Montreal Cognitive Assessment (MoCA): confirmatory factor analysis

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Received: 20 August 2009 / Revised: 9 November 2009 / Accepted: 12 November 2009 / Published online: 25 November 2009

Abstract The Montreal Cognitive Assessment (MoCA) is a cognitive screening instrument created with the purpose of overcoming some of the insufficiencies of the Mini-Mental State Examination (MMSE). The MoCA evaluates more cognitive areas and is comprised of more complex tasks as compared with the MMSE, which makes it a more sensitive instrument in the detection of Mild Cognitive Impairment (MCI), a state that often progresses to dementia. In this study we performed an analysis of the psychometric and diagnostic properties of the Portuguese experimental version of the MoCA in a clinical sample of 212 subjects with MCI and several dementia subtypes in a memory clinic setting. Additionally, we performed a Confirmatory Factor Analysis (CFA) to assess the MoCA's latent factorial structure. In a clinical population, the MoCA is a valid and reliable instrument with good psychometric properties, revealing high sensitivity in identifying MCI and dementia patients who generally score within the normal range on the MMSE. By using the parcels method, CFA results showed very good/excellent adjustment indexes. The practical implications of this CFA study allow us to propose a two factor model factorial structure for the MoCA: a first factor designated MEMORY, which includes memory, language and orientation subtests (the latter being closely correlated with the former), and a second factor designated ATTENTION/EXECUTIVE FUNCTIONS, comprised of attention, executive functions and visuospacial abilities tasks.

Keywords Montreal Cognitive Assessment · Mild Cognitive Impairment · Dementia · Confirmatory factor analysis

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Introduction

The Montreal Cognitive Assessment (MoCA) is a cognitive screening instrument created by Nasreddine et al. [25] to detect Mild Cognitive Impairment (MCI), a state that often precedes dementia. The MoCA should overcome some of the known insufficiencies of the Mini-Mental State Examination (MMSE) [13], especially the fact that patients with MCI often score in the normal range for the MMSE. The detection of patients with cognitive deficits which do not fulfill the criteria for dementia is crucial in clinical practice or research and has been object of discussion in several studies [29].

The MoCA is a one-page test with a maximum score of 30 points http://www.mocatest.org. The authors describe this test as measuring eight cognitive domains through several tasks: short-term memory (delayed recall, 5 points); visuospacial abilities (cube, 1 point; clock drawing, 3 points); executive functions (trail-making test B, 1 point;

phonemic verbal fluency, 1 point; verbal abstraction, 2 points); attention, concentration and working memory (cancellation, 1 point; subtraction, 3 points; digit span, 2 points); language (nomination, 3 points; sentence repetition, 2 points); and orientation to time (3 points) and space (3 points). To correct for educational effects found in the original study, an additional point is given to subjects with 12 or fewer years of education [25].

In the original study [25] the authors established a cut-off point of 26, common to the English and French versions. Based on this score, the results showed the MoCA's excellent sensitivity in the identification of MCI (90%) and Alzheimer's disease (AD) (100%). For the MMSE they found a poor sensitivity for MCI (18%) and AD (78%), although it has excellent specificity (100%), suitable for the identification of normal controls (NC) who score above the cut-off point of 26. The measures of reliability concerning the MoCA showed a high test–retest reliability (0.92) and good internal consistency (0.83). All the items of the MoCA discriminate between at least two groups (NC, MCI and AD), and most of them discriminate among the results of all the groups [25].

Other validation studies of the MoCA in different countries, which also established a comparison with the results in the MMSE, showed a pattern of results similar to the original study with regard to sensitivity. The MoCA seems to identify cognitive decline earlier in the course of the disease than the MMSE [32], and has a high sensitivity in the detection of MCI and dementia [4, 36]. The MoCA's specificity is lower than the MMSE's, with values ranging from 50% (100% with the MMSE) [36] to 43.5% [4], showing a high percentage of false positives with the original cut-off score of 26.

The Portuguese experimental version of the MoCA has been the subject of several studies conducted in Portugal. The results of these studies seem to confirm the validity and clinical utility of this instrument [10–12].

Objectives

The purpose of this study was to determine the MoCA's potential as a screening instrument for mild to moderate cognitive decline by assessing its psychometric properties, its diagnostic capacity and by subjecting it to a Confirmatory factor analysis (CFA). CFA was performed in order to examine different models of the factorial structure of the Portuguese experimental version of the MoCA, as a contribution to a better knowledge of its psychometric properties and its potential as a cognitive screening instrument, including alternative score interpretation methods. CFA allows us to infer relations between the observed measures and a latent hypothetical factorial structure postulated by the investigator based on theory and/or empirical investigation. The goal is to assess the degree to which a formerly determined factorial structure is consistent with the sample results [6]. In this context, CFA was used to assess the relation between the cognitive domains assessed by the MoCA: memory; visuospacial abilities; executive functions; attention, concentration and working memory; language; and orientation [25]. This analysis had never been previously performed for this test.

Table 1 Demographic characteristics

N	*212*
Gender (M/F)	77 (36.3%) males
	135 (63.7%) females
Age (years)	Mean = 71.78 (SD = 9.11 A; range 44–90)
	≤64: 42 (19.8%)
	65–69: 33 (15.6%)
	70–74: 43 (20.3%)
	75–79: 50 (23.6%)
	≥80: 44 (20.8%)
Education (years)	1–4 years: 117 (55.2%)
	5–9 years: 31 (14.6%)
	10–12 years: 24 (11.3%)
	13–18 years: 25 (11.8%)
Diagnosis (N)	MCI: 82 (38.7%)
	AD: 70 (33.0%)
	VaD: 25 (11.8%)
	ODD: 35 (16.5%)

Materials and methods

Participants

The study participants were recruited at the Dementia Clinic, Neurology Department of Coimbra University Hospital: 82 individuals with MCI, 70 with mild to moderate AD, 25 with mild to moderate vascular dementia (VaD), and 35 with other degenerative dementias (ODD)[1] of the same severity. Demographic characteristics of the study sample are presented in Table 1. All patients underwent thorough biochemical, neurological and image studies—structural (CT and/or MRI) and functional (SPECT and/or PET)—which are essential to exclude other causes and forms of dementia. Cognitive evaluation used as a diagnostic tool included the MMSE, the Alzheimer's Disease Assessment Scale (ADAS-Cog) [34] and a

[1] The ODD group was formed of patients diagnosed with frontotemporal dementia and dementia with Lewy bodies. The creation of a single experimental group is justified by the low prevalence of these pathologies in the population and relatively to AD.

comprehensive neuropsychological evaluation. The MoCA was never used for diagnostic purposes. Classification for study sub-groups was established based on international criteria for the diagnosis of MCI [30], probable AD [1, 23], VaD [33], Frontotemporal Dementia (FTD) [27], and Lewy Bodies Dementia (LBD) [22]. According to the most recent guidelines [29, 31], MCI patients were classified as amnestic MCI (single or multidomain) or non-amnestic MCI (single or multidomain). All MCI patients selected for this study were of the amnestic type.

For this specific study, several inclusion criteria were considered in subject selection: (1) clinical probable diagnosis of MCI, AD, VaD, FTD, and LBD, according to international criteria previously mentioned; (2) global severity classification according to the Clinical Dementia Rating scale (CDR) [24], where a classification of 0.5 refers to a clinical state of MCI, 1 to mild dementia and 2 to moderate dementia; (3) stable condition, without acute comorbidities. The exclusion criteria were: (1) an MMSE score of <10 (severe dementia); (2) recent psychiatric comorbidity (clinically diagnosed in the 6 months prior to the current neuropsychological evaluation); (3) motor and/or sensorial deficits that constituted confounding variables in the assessment of high nervous functions.

The Coimbra University Hospital's Neurology department allowed this study to be incorporated into the routine neuropsychological assessment of patients treated regularly in the general neurology and dementia outpatient clinic. All patients and their families were informed about the relevance of their participation and fundamental contribution in this study as part of their usual treatment routine. Oral informed consent to participate in the study was given by the patient or a family member legally competent to do so. The patient's willingness and physical and psychological capacity to participate in the study were respected at all times. No reward was given a posteriori to any of the participants involved.

Statistical analysis

Statistical analyses were performed using SPSS (Statistical Package for the Social Sciences) version 16.0. CFA was performed using AMOS software (Analysis of Moment Structures) version 6.0 [2].

The following guidelines could be used concerning model fit criteria and acceptable fit interpretation [5, 16, 20, 35]: the Goodness-of-Fit Index (GFI) and the Adjusted Goodness-of-Fit Index (AGFI), that is, GFI adjusted for the number of variables and the degrees of freedom, where values greater than 0.90 and close to 0.95 reflect a good fit. The Comparative Fit Index (CFI) with values closer to 1.0 implying good model fit and also the advantage of reflecting the degree of fit relatively well at all sample sizes. The Incremental Fit Index (IFI) attempts to correct the possibility of the chosen model being improved (made closer to 1.0) by merely adding parameters. The Root Mean Square Error of Approximation (RMSEA) values closer to 0.06 or very close to 0 suggest good model fit. Another significant data adjustment index is the χ^2 test, which allows us to test the adjustment between the model and the observed covariances matrix; a lower value represents a better adjustment. The power of the test to detect incongruence between the theory and the data is controlled mostly by the sample's size. With a small sample, an alternative hypothesis which derives from the null hypothesis may have a small probability to withhold a significant χ^2 [7]. Therefore, the ideal scenario will be to have a non-significant χ^2 because we want to infer the validity of the hypothesis of the independence between the model and the data [3]. Indexes AGFI, GFI and CFI bellow 0.90 suggest the need to improve the model [9], as CFI values close to 1.0 and low RMSEA values (close to 0) indicate a good model adjustment [21]. In order to minimize the probability of the occurrence of type I and type II errors, Hu and Bentler [16] suggest a combining rule which requires a CFI value very close to 0.95 and an RMSEA value contiguous to 0.06.

Results

Psychometric properties

The MoCA's total score was not affected by gender in any of the groups. For MCI patients, there was a statistically significant difference in results due to age [$F(4,77) = 5.157$, $p \leq 0.001$], and education [$F(4,77) = 22.239$, $p \leq 0.001$]. The scores of dementia patients were not affected by age, but they were by education [$F(4,125) = 5.157$, $p \leq 0.001$].

The MoCA had a high internal consistency (Chronbach's $\alpha = 0.90$), indicating a good relation between its subtests. Test–retest reliability was analysed in a subsample of 21 subjects (MCI, AD, and VaD), assessed 5.43 ± 1.73 months apart. There was a high correlation between the two evaluations ($r = 0.87$, $p \leq 0.001$).

Group differences in MoCA total score

The mean MoCA score was 14.40 points (SD = 6.78). By comparison, patients scored 23.45 (SD = 5.15) on the MMSE. There was a statistically significant difference between the four groups on the MoCA's global score [$F(3,208) = 45.619$, $p \leq 0.001$]. MCI patients had the best performance ($M = 19.62$, SD = 5.49), followed by VaD ($M = 13.48$, SD = 5.35), ODD ($M = 11.14$, SD = 5.27),

and AD patients ($M = 10.23$, SD = 5.07). Post-hoc analysis showed significant differences between MCI and all dementia groups (AD, VaD, and ODD). Within the dementia spectrum, VaD patients performed significantly better than AD patients.

Sensitivity of MoCA and MMSE

Sensitivity was determined based on the original cut-off score of 26. An additional point was given to subjects with ≤12 years of education. The global score correctly identified 84.1% of MCI patients and 100% of dementia patients. The MMSE score identified 9.9% MCI and 56.2% dementia patients.

Correlation between MoCA and other cognitive tests

The MoCA's total score had a high correlation with the MMSE: $r(211) = 0.82, p \leq 0.001$. With the ADAS-Cog we found a moderate negative correlation: $r\ (83) = -0.76$, $p \leq 0.001$. A more detailed analysis between these instruments showed moderate to high significant correlations between common assessed areas: memory, orientation, language, visuospacial/constructive ability and attention, revealing a good concurrent validity of these instruments (Table 2).

Confirmatory factor analysis

As the starting point of CFA we used the division in cognitive domains postulated in the original study previously mentioned [25]. All subtests which form this instrument kept the same organization, except for Digits Backwards which was considered, for this analysis, a memory subtest.

We analysed several factorial models through different adjustment indexes: (1) Model 1 (one factor) includes all subtests which therefore form a global factor, COGNITION; (2) Model 2 (two factors) includes a first factor, MEMORY, comprised of memory (delayed recall + digits backwards), language (nomination + sentence repetition), and orientation subtests, and a second factor, ATTENTION/EXECUTIVE FUNCTIONS, comprised of visuospacial abilities (cube copy + clock drawing), executive functions (trail making test B + phonemic verbal fluency + abstraction), and attention (digits forwards + cancellation + subtraction) subtests.

CFA results are presented in Table 3. Model 1, formed by a single factor (COGNITION) presented the following adjustment indexes: 29.661 (χ^2), 0.958 (GFI), 0.902 (AGFI), 0.957 (CFI), 0.957 (IFI), 0.104 (RMSEA). Results with this model were improved following adjustment through the establishment of a correlation between the error variance of memory and orientation (Model 1a): 19.533 (χ^2), 0.972 (GFI), 0.926 (AGFI), 0.976 (CFI), 0.976 (IFI), 0.083 (RMSEA).

Model 2, the two factor model (MEMORY and ATTENTION/EXECUTIVE FUNCTIONS) presented the following results: 18.817 (χ^2), 0.974 (GFI), 0.932 (AGFI), 0.977 (CFI), 0.978 (IFI), 0.080 (RMSEA). The establishment of a correlation between the error variance of memory and orientation, as in the previous model, resulted in the improvement of the model, as shown in the following adjustment indexes (Model 2a): 13.996 (χ^2), 0.980 (GFI), 0.939 (AGFI), 0.985 (CFI), 0.986 (IFI), 0.069 (RMSEA). Results of the four models are presented in Table 3. Model 2a presented the best adjustment indexes.

In order to assess the discriminative capacity of the factors found in CFA, we conducted a one-way ANOVA followed by post hoc Tukey HSD. There are significant differences in the sample's results in the subtests that form factor 1 (MEMORY) [$F(3, 208) = 36.334$; $p \leq 0.001$). According to post hoc analysis, statistically significant differences occur between MCI and AD (IC 95%] 3.70; 6.35[; $p \leq 0.001$), MCI and VaD (IC 95%] 0.82; 4.55[; $p \leq 0.001$), and MCI and ODD (IC 95%] 2.75; 6.04[; $p \leq 0.001$). In the dementia groups, there are significant differences between VaD and AD (IC 95%] 0.44; 4.24[; $p < 0.01$).

Table 2 Correlation between MoCA and other cognitive tests

MoCA	MMSE	ADAS-Cog
Total	0.823**	−0.762**
Memory	0.475**	−0.378**
Orientation	0.909**	−0.854**
Memory + Orientation	0.834**	−0.672**
Language	0.420**	−0.178
Visuospacial/constructive abilities	0.555**	−0.605**
Attention	0.651**	–

** $p < 0.001$

Table 3 MoCA: CFA results

Model	χ^2	*df*	*p*	GFI	AGFI	CFI	IFI	RMSEA
Model 1 (1 Factor)	29.661	9	0.001	0.958	0.902	0.957	0.957	0.104
Model 1a (1 Factor)	19.533	8	0.012	0.972	0.926	0.976	0.976	0.083
Model 2 (2 Factors)	18.817	8	0.016	0.974	0.932	0.977	0.978	0.080
Model 2a 2 Factors)	**13.996**	**7**	**0.051**	**0.980**	**0.939**	**0.985**	**0.986**	**0.069**

Bold values enlighten the CFA model with best adjustment indexes

χ^2 Chi-square, *df* degrees of freedom, *GFI* Goodness-of-fit Index, *AGFI* Adjusted Goodness-of-fit Index, *CFI* Comparative Fit Index, *IFI* Incremental Fit Index, *RMSEA* Root Mean Squared Error of Approximation

We found significant differences between the groups concerning the items that form factor 2 (ATTENTION/EXECUTIVE FUNCTIONS): $F(3, 208) = 30.485$; $p \leq 0.001$. Post hoc analysis showed statistically significant differences between MCI and AD (IC 95%] 3,05; 5,66[; $p \leq 0.001$), MCI and VaD (IC 95%] 1.63; 5.29[; $p \leq 0.001$), and MCI and ODD (IC a 95%] 2.56; 5.79[; $p \leq 0.001$). There are no significant differences between dementia groups for this factor.

Discussion

In this study we examined the psychometric properties of the MoCA in a clinical population. Our main findings can be summarized as follows: The MoCA's results were not affected by gender. Age had different effects as we found statistically significant differences in MCI patients (between the youngest and the oldest patients), which did not happen in dementia patients. Education affected results in all groups: a higher education corresponds to a higher total score. These results, if corroborated in further studies, should be considered in the establishment of cut-off scores for the Portuguese population.

In this clinical sample, the MoCA was a precise instrument with high internal consistency, indicating a strong relationship between its items. This result was higher than those present in other studies with this instrument [4, 18, 25]. Test–retest reliability was also high, a result consistent with other studies [14, 25].

The MoCA had good discriminant validity, as the total score allowed the distinction between MCI and dementia patients. Within the dementia spectrum, it was also able to differentiate AD and VaD patients, suggesting the capacity to distinguish primarily degenerative from vascular cognitive deficits. This instrument had a high sensitivity in the detection of MCI and mild to moderate dementia, clearly better than the MMSE. These results corroborate the MoCA's utility as a potential complement to the MMSE as a cognitive screening instrument, especially in the detection of MCI patients.

The MoCA's concurrent validity was determined by a high correlation with the MMSE and ADAS-Cog total scores, and by moderate to high correlation values between common cognitive areas assessed by all instruments. The MoCA's validation studies have focused on a more direct comparison with the MMSE. The correlation between the two instruments has values ranging from 0.41 [4] to 0.87 [25]. Other studies have shown modest to high correlations with other tests [4] and neuropsychological batteries [18].

More recently, the MoCA has been used in several studies with different clinical populations: detection of cognitive deficits in Parkinson's disease [8, 14, 26, 38], brain tumours [28], and clinical trials in AD [37].

The validation study of the MoCA performed through CFA is an original study. Results found confirmed construct validity of this instrument with a two factor model in which we correlate the error variances of memory and orientation, resulting in very good to excellent adjustment indexes. The investigators' decision to test digit forwards and backwards as part of different factors eradicates a common distinction present in the literature which considers these two tasks as examining "partially different mechanisms" [15], or specific aspects of memory. Digits forwards requires only straight recall. Digits backwards, on the other hand, is a working memory task, more complex, with a higher cognitive demand, which therefore requires higher mental manipulation and number visualization as well as information codification for posterior cognitive processing [17, 19].

The practical implications of this CFA study allow us to propose a two factor model factorial structure for the MoCA: a first factor designated MEMORY, which includes memory, language and orientation subtests (the latter being closely correlated with the first), and a second factor designated ATTENTION/EXECUTIVE FUNCTIONS, comprised of attention, executive functions and visuospacial abilities tasks. Such levels of confirmatory model fit offer plausibility and trustworthiness of the hypothesized two factor structure (model 2a, 2 factors), especially given the fact that the competing factor models, also tested, specifying alternative dimensionalities, presented evidently lesser levels of fit.

This is the first known study of CFA with the MoCA. It is important to acknowledge the lack of other CFA studies which would allow a more specific analysis of MoCA results, or of other cognitive impairment screening instruments.

The present study has some limitations regarding the non-equivalent clinical subgroups size (MCI, AD, VaD and ODD), which compromises the possibility of performing a more detailed analysis of the MoCA's structure in the clinical subgroups, and the former generalization of the present results.

In the future, it will be interesting to analyse whether the factorial structure found in this heterogeneous sample is corroborated in more specific samples: MCI (in its different subtypes), AD and normal controls—according to the most common typology of cognitive ageing studies. It will also be important to perform a similar study in forms of dementia characterized by an impairment of executive functions, such as frontotemporal dementia (FTD) and VaD, in which this analysis could be particularly interesting. There has been a lack of studies and specific cognitive screening instruments to assess executive functions, which are especially impaired in such pathologies. If a convergence of results is found, in the future it will be possible to

consider an alternative form of interpretation of the MoCA's results: subjects' total score and aggregates of results by groups of items or functions—factor 1 (MEMORY) and factor 2 (ATTENTION/EXECUTIVE FUNCTIONS).

Acknowledgments We thank Paul Moreira for his assistance in TTR production. Carlos Ribeiro is a recipient of a BI fellowship (PTDC-64593-PR011901-BI) and Rita Costa is a recipient of a PhD fellowship (SFRH/BD/41799/2007). This work was supported by the Portuguese Foundation for Science and Technology (FCT) through PTDC/SAU-NEU/64593/2006, by POCI 2010 (Programa Operacional Ciência e Inovação 2010) and with the participation of the European Communitarian Fund FEDER.

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