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Strengths and Limitations of the MoCA for Assessing Cognitive Functioning: Findings From a Large Representative Sample of Irish Older Adults

Robert F. Coen, PhD[1], Deirdre A. Robertson, PhD[2], Rose Anne Kenny, MD[2], and Bellinda L. King-Kallimanis, PhD[2]

Abstract

Background: The Montreal Cognitive Assessment (MoCA) is a very widely used test for mild cognitive impairment. Differing recommendations have been made regarding its utility in providing a profile of performance across several cognitive domains. **Objectives:** To examine the factor structure of the MoCA in a nationally representative population study of older Irish adults and evaluate its utility in providing domain-specific information. **Methods:** A cross-sectional analysis of wave 1 data from the Irish Longitudinal Study on Ageing was undertaken. Data from a subset of 2342 participants assessed using the MoCA were analyzed using both confirmatory factor analytic (CFA) and exploratory factor analytic (EFA) methods. **Results:** Mean age was 72.64 (range 65 to 98), 53% female. The CFA provided evidence of adequate overall model fit for a previously proposed 6-factor model. In contrast, EFA yielded a 3-factor solution and test items cross-loaded onto a number of factors with no clear pattern of underlying cognitive domains. Using EFA to explore the 6-factor model yielded good fit, but again test items cross-loaded onto a number of factors with no clear pattern evident. **Conclusion:** Lack of concordance between the CFA and EFA findings demonstrates that the correspondence between individual tests and their assumed cognitive domains is not robust, reflecting at least in part a current lack of consensus on how core cognitive constructs are defined and on what subcomponents can be subsumed under different cognitive domains. The MoCA should not be viewed as a substitute for more in-depth neuropsychological assessment when domain-specific information is required.

Keywords

MoCA, factor analysis, cognitive domains, neuropsychological assessment

Introduction

The Montreal Cognitive Assessment (MoCA), originally developed as a brief cognitive screening tool to assist first-line physicians in detecting mild cognitive impairment (MCI), has become widely used in clinical and research settings.[1,2] In comparison with the ubiquitously used Mini-Mental State Examination (MMSE[2,3]), the MoCA has been shown to be more sensitive to MCI in a variety of settings and conditions.[3-12] By far, the most common practice is to interpret the total MoCA score in relation to a pass/fail cut-point, but there is no clear agreement as to the most appropriate cut-point.[13-17] The originally recommended cut-point (normal range $\geq$26/30) has consistently been shown to maximize sensitivity at the cost of yielding unacceptably low specificity and lower cut-points have been recommended,[13-17] a contention further supported by findings from recently published population-based normative studies.[17,18] Paul et al[16] found that while the MoCA correlated well with more comprehensive neuropsychological testing (Repeatable Battery for Assessment of Neuropsychological Status [RBANS][19]) the recommended MoCA cut-point did not discriminate groups on MRI brain volume variables, and performance was within normal limits on the RBANS and other measures for individuals performing below the MoCA cut-point. These findings suggest that one should be cautious when interpreting MoCA performance based on the total score alone.

In addition to providing a total score, the MoCA consists of a number of separate tasks, on which the original authors, a priori, proposed a structure where individual items are to be grouped under 6 different cognitive domains, based on content.[1] These domains include short-term memory; visuospatial

[1] Mercer's Institute for Research on Ageing, St James's Hospital, Dublin, Ireland
[2] TILDA (The Irish Longitudinal Study on Ageing), Lincoln Gate, Trinity College Dublin, Dublin, Ireland

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Corresponding Author:
Robert F. Coen, Mercer's Institute for Research on Ageing, St James's Hospital, Dublin 8, Ireland.
Email: rcoen@stjames.ie

abilities; executive functioning; attention, concentration, and working memory; language; and orientation to time and place. Somewhat contradictory, these domains do not directly map onto the subheadings that appear on the MoCA test itself (in which visuospatial/executive is a combined heading, and naming, memory, attention, language, abstraction, delayed recall, and orientation are the other headings). Freitas et al undertook to evaluate the proposed a priori 6-domain structure in a sample of 830 participants (650 healthy, 90 MCI, and 90 Alzheimer's disease) and on the basis of confirmatory factor analysis (CFA) results, which reported that this structure was supported.[14] They concluded that clinicians and researchers can use the MoCA total score and also the 6 latent dimensions (cognitive domains) to achieve a better understanding of the individual's cognitive profile.

In contrast, Moafmashhadi and Koski[20] investigated the limitations of interpreting failure on the individual MoCA subtests in a sample of 185 geriatric memory clinic attenders (including 50% MCI, 26% dementia, and 10% normal cognition on neuropsychological testing). Principal components factor analysis identified 5 cognitive domains: memory, language, visuospatial ability, attention/processing speed, and cognitive control (executive functioning). Orientation was subsumed under memory. Their factor analysis findings are therefore broadly in keeping with those of Freitas et al.[14]

Importantly, Moafmashhadi and Koski also went on to conduct a detailed analysis of the concordance between these cognitive domains and performance on a very detailed battery of standardized neuropsychological tests (eg, subtests from the Wechsler Memory Scale-III, Wechsler Adult Intelligence Scale-III, and others).[20] Receiver–operating characteristic curve analysis revealed that the predictive accuracy of the MoCA domain scores for classifying patients as impaired or unimpaired within a cognitive domain was poor (ranging from 0.60 to 0.71). They reported that the visuospatial/executive subtest total score yielded fair accuracy (71%) for predicting visuospatial impairment but cautioned that for the other cognitive domains the level of predictive accuracy was unacceptably poor. They concluded that the individual MoCA items and domain subgroups yield insufficient information to draw conclusions about impairment in specific cognitive domains, and recommended referral for neuropsychological assessment when the overall pattern of cognitive ability is required for diagnostic purposes.

In attempting to reconcile the discrepancies between the conclusions and recommendations from Freitas et al[14] on the one hand and Moafmashhadi and Koski[20] on the other, it is essential to appreciate, as discussed by the latter authors, that virtually all cognitive tasks are multifactorial and measure abilities across multiple domains. In contrast, a majority of test users tend to think in terms of tests as measuring single cognitive constructs (eg, memory, attention, and verbal fluency) and evidence to support this is frequently sought using statistical methods such as exploratory factor analysis (EFA) or CFA. The EFA analysis imposes no specific structure on the data, it is a data-driven technique, whereas CFA tests an a priori structure on the data such that items are associated with domains before the analysis is conducted.

Aim of the Present Article

In an attempt to understand discrepancies between the findings and the recommendations from Freitas et al[14] and Moafmashhadi and Koski[20] regarding the use of the MoCA to evaluate individual cognitive domains, a 2-stage approach was taken in this study. Stage 1: CFA will be used to evaluate the 6-factor model proposed by Nesreddine et al and Freitas et al.[1,14] If the fit of the 6-factor model is satisfactory, no additional analysis will be conducted; however, if the fit of this model is unsatisfactory, a second stage will be carried out. Stage 2: EFA will be used to explore alternative factor structures of MoCA.

Methods

Sample

Data were taken from wave 1 of The Irish Longitudinal Study on Ageing (TILDA), a prospective, population representative sample of community-dwelling adults aged 50 and older in the Republic of Ireland. Participants who reported a doctor's diagnosis of dementia or who were unable to personally consent to participation due to a severe cognitive impairment (judged at an interviewer's discretion) were not included in wave 1 of the study. Ethical approval was obtained, and all participants provided signed informed consent prior to the study. All experimental procedures adhered to the Declaration of Helsinki. Wave 1 data were collected between July 2009 and June 2011. The full cohort and assessment has been described in detail elsewhere,[21,22] but in brief, 8504 participants aged 50 and older, and their partners of any age, were interviewed in their own homes followed by a nurse-administered health assessment at 1 of 2 dedicated health centers. Participants unable or unwilling to attend a health assessment center received a modified nurse-delivered health assessment at home. The response rate to the interview was 62.0%, and 61.6% of participants completed the health assessment. For the purposes of this analysis, however, we only included participants who were aged 65 or older (n = 2380). There was a small number of missing data in the sample across all variables (n = 38). This left a final sample size of 2342. Cognition was evaluated using the MoCA. On the MoCA, possible scores range from 0 to 30 with an additional point given for a participant with less than 12 years of education. The original English version of the test (version 7.1) was used.

Descriptive Variables

Education was categorized into 3 levels: none or primary, secondary, and tertiary. None or primary education typically corresponds to fewer than 11 years of full-time education. Secondary education is regarded as completion of the junior certificate, group certificate, or leaving certificate and typically corresponds to between 11 and 13 years of full-time education. The final group includes those who completed tertiary education, including any diploma or degree at any time in their lives. Age was included as a continuous variable and gender as a binary variable. All variables were ascertained during the in-home interview.

Statistical Analysis

Descriptive statistics were examined to investigate missing data and ceiling and floor effects for each item of the MoCA. In addition to this, we used both CFA and EFA. In stage 1, a CFA was performed and in stage 2 an EFA was performed. Because the MoCA items are dichotomous, we used the weighted least squares estimator with a mean and variance adjustment (Mplus 7) in all analyses. Overall model fit was assessed using the χ^2 test of exact fit, the root mean square error of approximation (RMSEA), and the weighted root mean square residual (WRMR). A nonsignificant χ^2 value indicates good fit. It is, however, sensitive to small deviations between the model and the data when, as in this study, the sample size is large. Approximate fit indices were also examined, and conventional cut-off values were applied to determine satisfactory fit: an RMSEA <0.05 and a WRMR of approximately 1. Fit was considered satisfactory when both the RMSEA and the WRMR were acceptable.

Stage 1. In this stage, we fit the 6-factor model proposed by Frietas et al[14] using CFA to assess the validity of this model. The overall model fit was assessed using the χ^2 test, RMSEA, and WRMR. If the fit of this model was poor, the modification indices were investigated. The modification index has a χ^2 distribution with 1 degree of freedom. Due to the large number of statistical tests under consideration, we took a conservative approach and only considered modification indices to be worth investigating when the modification index was >10.00 and also substantively interpretable.

Stage 2. In this stage, we used EFA to explore whether an alternative model structure was present in the TILDA data. To determine the number of factors present, we relied on the scree plot and eigenvalues. The default geomin rotation (a type of oblique rotation) was used so that correlations between the factors were provided. We used information from both sources while also considering the substantive interpretation of the factors along with the size of the factor loadings. Factor loadings greater than 0.30 were considered substantive. Overall model fit was assessed using the χ^2 test and RMSEA as well as interpretability of the extracted factors.

Results

There were 2342 participants, with an average age of 72.64 (range 65 to 98), and just over half were female. The sample demographic characteristics are presented in Table 1.

Table 2 provides an item analysis (% correct responses) for each of the MoCA items. The items Clock Contour, Camel, Attention Forwards, First Serial 7 s Subtraction, Day, Month, Year, Place, and City had high hit rates (>90%). The lowest hit rate items (<40%) were Cube and recalling the fourth word (Daisy), and the rates for these items were similar for Freitas et al.[14]

Table 1. Demographic Characteristics of the Sample.[a]

Variable	Mean (SD) or %
Age	72.64 (6.19, range 65-98)
Gender—female	51.79 (n = 1213)
Education	
No primary/primary	38.46 (n = 900)
Secondary	34.66 (n = 811)
Tertiary	26.88 (n = 629)
MoCA	22.89 (4.39, range 2-30)

Abbreviations: MoCA, Montreal Cognitive Assessment; SD, standard deviation.
[a]n = 2342.

Table 2. Distribution of Responses for the Individual MoCA Items.

MoCA Item	% Correct Response
Trails	72.70
Cube	39.34
Clock Contour	97.88
Clock Numbers	87.07
Clock Hands	69.86
Lion	89.86
Rhino	59.57
Camel	90.67
Attention Forwards	94.32
Attention Backwards	81.51
Attention Letters	89.95
Serial 7s 93	92.99
Serial 7s 86	74.09
Serial 7s 79	77.96
Serial 7s 72	77.88
Serial 7s 65	72.54
Sentence John	86.04
Sentence Cat	57.46
Language Fluency	52.40
Abstract1	73.80
Abstract2	73.90
Delayed Recall Face	45.47
Delayed Recall Velvet	64.31
Delayed Recall Church	50.73
Delayed Recall Daisy	31.13
Delayed Recall Red	43.63
Orientation Day	97.16
Orientation Date	90.17
Orientation Month	98.09
Orientation Year	97.71
Orientation Place	98.22
Orientation City	99.62

Abbreviation: MoCA, Montreal Cognitive Assessment.

Stage 1

The 6-factor model originally proposed had adequate overall model fit (Model 1_{CFA}, Table 3); however, there was an

Table 3. Adjusted Chi-Square and Overall Goodness-of-Fit Test Results for the Confirmatory Factor Analysis and Exploratory Factor Analysis of the MoCA Model.

Model	Adjusted χ^2 (*df*)	*P* Value for Overall Model Fit	RMSEA (90% Confidence Interval)	WRMR
Stage 1: confirmatory factor analysis				
$M1_{CFA}$: Frieta's model	1104.27 (448)	<.0001	0.025 (0.023-0.027)	1.40
$M2_{CFA}$: removed city	1116.27 (418)	<.0001	0.027 (0.025-0.029)	1.40
$M3_{CFA}$: remove fluency from Language	1115.38 (419)	<.0001	0.027 (0.025-0.029)	1.40
$M4_{CFA}$: add attention letters to EF	996.71 (418)	<.0001	0.024 (0.022-0.026)	1.32
Stage 2: exploratory factor analysis				
$M1_{EFA}$: 1 factor	1052.94 (252)	<.0001	0.037 (0.035-0.039)	NA
$M2_{EFA}$: 3 factors	459.18 (187)	<.0001	0.025 (0.022-0.028)	NA
$M3_{EFA}$: 6 factors	182.70 (130)	.0016	0.013 (0.008-0.017)	NA

Abbreviations: CFA, confirmatory factor analysis; EFA, exploratory factor analysis; EF, executive function; MoCA, Montreal Cognitive Assessment; NA, not applicable; RMSEA, root mean square error of approximation; WRMR, weighted root mean square residual.

"empty cell" warning with respect to the item Orientation—City. Descriptive statistics had already indicated that nearly all respondents (99.7%) had answered that item correctly; therefore, the item was removed (Model 2_{CFA}, Table 3) and no additional errors were identified. In the model without city, all factor loadings were significant with the exception of the factor loading from Language on Language Fluency ($\lambda = -0.015$. $P = .899$). We removed the loading and reassessed the fit. Removal of the item did not significantly deteriorate the model fit, and effect on estimates and other fit statistics was minimal. As a CFA model with fewer parameters has great parsimony, we opted for this new model (Model 3_{CFA}, Table 3). As the overall model was still only marginally satisfactory, we investigated the modification indices, and expected parameter changes, while considering whether the suggested changes were substantively understandable. We found the item assessing the respondents' ability to correctly tap when the letter A was said was not solely associated with the latent variable assessing attention, concentration, and working memory but that it was also significantly associated with executive functioning. The inclusion of this additional parameter significantly improved fit, χ^2diff(1) = 65.98, $P < .001$: Model 4_{CFA}, (Table 3).

Table 4. EFA: 3 Factors Not Clearly Defined With Many Items Cross-Loaded Onto Multiple Factors.

Item	Factor 1	Factor 2	Factor 3
Trails	.27[a]	.20[a]	.50[a]
Cube	.31[a]	.37[a]	.16[a]
Clock 1	.61[a]		.56[a]
Clock 2	.44[a]		.54[a]
Clock 3	.42[a]		.41[a]
Lion	.52[a]	.45[a]	
Rhino	.42[a]	.45[a]	
Camel	.59[a]	.40[a]	
Attention Forwards		.48[a]	
Attention Backwards		.35[a]	.23[a]
Attention Letters		.28[a]	.27[a]
Sentence 1	−.21[a]	.59[a]	
Sentence 2		.66[a]	
Verbal Fluency		.38[a]	.31[a]
Abstraction 1		.40[a]	
Abstraction 2		.49[a]	.17[a]
Memory items (5)	.09[a]	.14[a]	.36[a]
Serial 7s (5)		.35[a]	.36[a]
Date			.63[a]
Month			.82[a]
Year			.75[a]
Day			.72[a]
Building			.35[a]

Abbreviation: EFA, exploratory factor analysis.
[a]Significantly loaded onto factor.

Stage 2

Due to high correlations between the individual items, we summed the items for the 5 memory items (range 0 to 5) and for the 5 serial 7s items (range 0 to 5) and for both we used the 0 to 5 score. A scree plot indicated that 1 or 3 factors would be appropriate while corresponding eigenvalues showed 3 values above 1.

First, we estimated the 1-factor model, which showed a large and significant chi square, χ^2 (252) = 1052.94, $P < .00001$, with acceptable but not good fit (Model 1_{EFA}, Table 3). All items loaded significantly onto 1 factor with values ranging from .354 to .718. As with the CFA the city item was problematic, therefore, we removed city from further analyses. The model without the city item also showed a large and significant chi square, χ^2 (230) = 1133.25, $P < .00001$.

Next, we estimated the 3-factor model. This showed improved fit, $\chi^2(187) = 459.17$, $P < .0001$, but items significantly cross-loaded onto a number of factors with no clear pattern (Model 2_{EFA}, Tables 3 and 4).

Finally, we estimated a 6-factor EFA although this had not been suggested by the scree plot but as this was the initial factor structure proposed by the MoCA authors.[1] This indicated good fit, $\chi^2(130) = 182.70$, $P = .0016$, but the item loadings did not correspond to the originally proposed factor structure nor to any identifiable pattern due to significantly numbers of cross-loadings (see Model 3_{EFA}, Tables 3 and 5).

Table 5. EFA: 6 Factors Not Clearly Defined With Many Items Cross-Loaded Onto Multiple Factors.[a]

Item	F1	F2	F3	F4	F5	F6
Trails	.43[b]			.32[b]		
Cube	.43[b]				−.31[b]	
Clock 1	.82[b]					
Clock 2	.83[b]					
Clock 3	.64[b]					
Lion	.19[b]	.58[b]	.25[b]			
Rhino		.63[b]	.25[b]			
Camel		.83[b]				
Attention forwards			.53[b]			
Attention backwards	.24[b]			.34[b]		
Attention Letters				.53[b]		
Sentence 1			.65[b]			
Sentence 2			.72[b]			
Verbal Fluency				.59[b]		
Abstraction 1						.38[b]
Abstraction 2						.84[b]
Memory items (5)				.43[b]		
Serial 7s (5)	.17[b]		.18[b]	.28[b]		
Date					.48[b]	
Month					.69[b]	
Year					.62[b]	
Day					.70[b]	

[a]Model statistics: $X^2(130) = 182.70$, $P < .001$; RMSEA = .013; CFI = .99; TLI = .99; SRMR = .034.
[b]Significantly loaded onto factor.

Discussion

In the present study, CFA provided evidence of an adequate overall model fit for the 6-factor model proposed by Freitas et al.[14] In contrast, EFA yielded a 3-factor solution, but test items cross-loaded onto a number of factors and no clear pattern was evident in terms of underlying cognitive domains. Using EFA to explore the proposed Freitas et al 6-factor model yielded good fit, but again test items cross-loaded onto a number of factors, and no clear pattern was evident and the item loadings did not correspond to their original findings. The lack of concordance between findings using CFA versus EFA indicates that the correspondence between individual tests and their assumed cognitive domains is not robust.

A limitation in the application and interpretation of factor analytic methods is the danger that when we impose a structure on data, we may to an extent find what we expect to find. This is compounded by an endemic lack of agreement on exactly what different cognitive tests measure, how we define core cognitive constructs, and what subcomponents can be subsumed under different cognitive domains, as discussed in a recent critical review of evidence-based science and practice in neuropsychology by Kaufman et al.[23] They identify the most critical current bottleneck to be the difficulty in achieving consensus frameworks for describing neuropsychological concepts and their measurement. As stated earlier, it is essential to appreciate that virtually all cognitive tasks are multifactorial and for accurate completion require ability across multiple domains, for example, clock drawing is cognitively complex, may be failed for a variety of reasons, and it is difficult to attribute failure to impairment in any 1 cognitive domain. However, tests are often assumed to be evaluating primarily 1 domain. Consider, eg, verbal fluency as assessed by asking respondents to say as many animals as they can think of in 1 min. Using this same task, different studies report having measured language,[24] semantic memory,[25] or executive functioning,[26] and this practice is the norm not the exception in the research and clinical literature. It is clear from our present findings that many tests cross-load onto several factors and are not clearly a measure of any single domain in isolation.

These issues have previously been highlighted by Jones and Gallo in their critical evaluation of the MMSE in which it was evident that different studies produce different factor solutions.[27] They found that previous studies revealed 2-, 3-, 4-, 5-, or 6-factor solutions and observed that, despite the seeming objectivity of statistical procedures there are very many assumptions and subjective decisions that determine the outcome. They also acknowledged that there is an "arbitrariness in the determination of the number of latent factors to retain" and commented that "investigators' a priori biases often drive the interpretation of factors."[p613] In their own analysis of the MMSE, they found that while the MMSE was "essentially unidimensional," 4-, 5-, 6-, and 7-factor solutions were supported. They settled on a 5-factor solution but acknowledged that other factor solutions could have been chosen. In their analysis of the MoCA, Freitas et al found good fits for 1-, 2-, and 6-factor solutions, but the 6-factor model showed a generally better fit.

The current findings resonate with Moafmashhadi and Koski's finding of poor predictive accuracy for MoCA in identifying domain-specific cognitive impairment as established by impaired range performance on detailed neuropsychological testing.[20] They found that MoCA subtest scores predicted cognitive impairment with an accuracy that was slightly above chance but fell short of the accuracy required for diagnostic applications. They recommended patients be referred for neuropsychological assessment when accurate domain-specific information is required. It can be concluded that while the MoCA is a useful screening instrument for MCI, it is limited in its ability to provide robust domain-specific information and should not be considered a valid substitute for more in-depth neuropsychological assessment. The issues that contribute to the MoCA's limitations in this regard go beyond the test itself, which is a well-designed, valid, and reliable short screening instrument and are just as pertinent in relation to any brief tests that attempt to evaluate performance in specific cognitive domains. Consensus on how we define core cognitive constructs and what subcomponents can be subsumed under different cognitive domains is clearly an area in need of urgent attention. The methods clinicians and researchers employ to provide objective support for the cognitive models we employ also warrant critical evaluation, as exemplified by the differing findings from the confirmatory and exploratory analyses in the present study.

One limitation of this study is that our samples are relatively cognitively healthy. The variance in some of the MoCA items was small as exemplified by having to remove the city item that had a correct response rate of 99.62%. In general, other items had a response rate of 70% and over. It will be informative to redo this analysis in a cognitively impaired or older population to establish whether the factors remain unchanged. As the MoCA will be repeated through subsequent waves of TILDA, it will be possible to repeat this analysis as the population gets older and more cognitively impaired.

In conclusion, while a CFA provides tentative support for the 6-factor structure of the MoCA, this does not hold when investigated using an EFA. While the MoCA has well-established utility as a screening tool for cognitive impairment it should not be viewed as a substitute for more in-depth neuropsychological assessment when domain-specific information is required.

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Authors' Note

Data: Researchers interested in using TILDA data may access the data for free from the following sites: Irish Social Science Data Archive (ISSDA) at University College Dublin http://www.ucd.ie/issda/data/tilda/. Interuniversity Consortium for Political and Social Research (ICPSR) at the University of Michigan http://www.icpsr.umich.edu/icpsrweb/ICPSR/studies/34315.

Declaration of Conflicting Interests

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