Comparison of Alternate and Original forms of the Montreal Cognitive Assessment (MoCA): an Italian normative study.

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Abstract

Objective. The Montreal Cognitive Assessment (MoCA) is a screening test widely used in clinical practice and suited for detection of Mild Cognitive Impairment. Alternate forms of the MoCA were developed to avoid "learning effect" in serial assessments, and the present study aimed at investigating inter-form parallelism and at providing normative values for the Italian versions of MoCA 2 and 3.

Method. Three separate convenience samples were recruited: the first (n= 78) completed three alternate MoCA versions for ascertaining inter-form parallelism; the second (n= 302) and the third (n= 413) samples were administered MoCA 2 or 3 to compute normative data.

Results. A three-step procedure complemented by confirmatory factor analysis and a mixed factorial ANOVA suggested that the three MoCA versions are not strictly parallel. Multiple linear regression analysis revealed that age and education significantly influenced MoCA 2 and 3 total scores. No significant effect of sex was found. From the derived linear equation, correction grids for MoCA 2 and 3 raw scores were built and equivalent scores computed. Inferential cut-off for adjusted scores, estimated using a non-parametric technique, were 17.49 for MoCA 2 and 18.34 for MoCA 3. Correlation analysis showed strong correlations of MoCA 2 (r= 0.69, $p < .001$) and MoCA 3 (r= 0.61, $p < .001$) adjusted total scores with MMSE adjusted scores.

Conclusion. The three MoCA forms are not strictly parallel. Specifically developed normative data must be adopted for using MoCA in serial cognitive assessments for clinical and research studies.

Key-words: statistical methods; norms; executive functions; aging; dementia; assessment

Introduction

The Montreal Cognitive Assessment (MoCA) is a 10-minute screening test developed to assist physicians in detecting cognitive impairment in a wide array of diseases [1-7].

The MoCA is thought to show higher sensitivity and specificity in identifying cognitive impairment with respect to Mini-Mental State Examination (MMSE) [8-10] This superiority is probably due to the structure of the MoCA, as it includes several tasks with visuospatial material along with tasks and procedures specifically assessing frontal/executive functions and attention [11]. The MoCA is characterized by good concurrent validity with respect to validated neuropsychological tests [12,13] and can detect cognitive impairment in different neurological disorders [13-15].

In order to limit possible "learning effects" in longitudinal assessments [16], alternate MoCA forms (MoCA 2 and 3) were developed replacing items of the original MoCA version (MoCA 1) with similar elements, but so far only mixed evidence of inter-form parallelism has been provided. While the German [17] and the French versions [16] of alternate MoCA forms were demonstrated to be parallel to the original MoCA version, a recent study employing a Rasch analysis-based approach showed significant differences in item difficulty between the three English MoCA forms [18].

The MoCA 1 has been translated into Italian [19], and the results of independent studies supported its validity for use in clinical practice [20-23]. In order to foster the employment of alternate forms of MoCA in clinical practice, Santangelo et al. [24] have translated the English versions of MoCA 2 and 3 into Italian, but until now no normative data have been made available.

The present study aimed at assessing the parallelism of the three Italian MoCA forms (MoCAs), and at providing normative data for alternate MoCA 2 and 3 encouraging their use in longitudinal clinical or research studies. Following the statistical procedures adopted for most Italian neuropsychological tests [25], we also computed correction factors to take into account the influence of the main sociodemographic variables (sex, age, and education) on the total score and to compare scores on alternate MoCA forms.

Method

Participants

We selected three separate convenience samples for: i) ascertaining the inter-form parallelism*; ii)* obtaining normative data for the MoCA 2, and iii) obtaining normative data for the MoCA 3.

The participants came from rural, suburban or urban areas, and were recruited through advertisements in religious communities, recreational centres, sport associations, educational facilities, and working places in all the five districts of Campania (South-western Italy).

As in most Italian normative studies (e.g., [20,25,26]) we did not adopt stringent sampling selection criteria, and included home-dwelling participants, independent in activities of daily living, and free from past or current neurological or psychiatric disorders; we did not exclude participants on the basis of presence of highly prevalent chronic medical conditions, such as hypertension, type II diabetes, heart failure, or chronic obstructive pulmonary disease. Although such conditions could lead to variable cognitive deterioration, this strategy aimed at recruiting a sample representative of the general population [25].

All participants also completed MMSE [27] and were excluded from analysis if their age- and education-adjusted score was lower than a cut-off point indicating cognitive deterioration not explained by "physiological" ageing or poor education: for participants younger than 80 we used Measso et al.'s [28] correction factors and a cut-off value of 23.8, whereas for participants aged 80 or more we used Magni et al.'s [29] correction factors and a cut-off value of 22 points.

Informed consent was obtained from all participants included in the study. The study was carried out in accordance with the Declaration of Helsinki on Ethical Principles for Medical Research.

Materials and procedure

MoCA and MMSE

MMSE [27] and MoCA [1] are routine cognitive screening tests rated on 30-point scale, that usually take 15 minutes or less to administer. The MMSE assesses general cognitive functioning by examining orientation, word recall, language abilities, attention and calculation, and visuospatial ability. Assessing many of the same cognitive domains as the MMSE, the MoCA explores a little more in depth the executive/visuospatial functions including tasks such as a clock-drawing test and a trail making test.

Inter-Form Parallelism

We used the alternate MoCA versions available in Italian [24], obtained replacing items of the original test with similar elements and closely matching the alternate English versions ([16]; for details see Supplementary Table 1).

Based on previous works, eligible participants were tested with MoCA 1, 2, and 3 within the same session; the three versions were administered back-to-back in counterbalanced order within 30 minutes (10 minutes per test) [16,17]. The tests were administered to the participants by the same examiner (C.P.), and a different examiner scored all responses (V.S.E.). After completing all three MoCA versions, the participants were assessed with the MMSE [27-29].

Normative data for MoCA 2 and MoCA 3

All participants were first administered the Italian MoCA 2 or 3, and then completed the MMSE [27-29].

Statistical analysis

Inter-Form Parallelism

In order to test the parallelism of the total score on the three MoCA versions, we used the three-step procedure suggested by Raykov et al. [30] using Mplus Version 6.12. This procedure is based on a latent variable approach in which the three measures (in this case, the MoCA versions) are considered as manifest indicators of a general latent factor in a one-factor confirmatory factor analysis (CFA) model. According Raykov et al. [30], (strict) parallelism holds if the three following conditions are met: i) equality of factor loadings; ii) equality of error variances; and iii) equality of manifest means (i.e., intercepts in the model). In three separate and sequential steps on the same sample we fitted one at time the CFA models with the constraint of equal loadings only (Model 1), equal error variances only (Model 2), and equal means only (Model 3), respectively. The next step was carried only when the previous step showed a tenable model fit, namely, a non-significant ($p >$ .05) chi-square model test. If the fit of any of the models was not tenable, we could conclude that the three measures could not be considered strictly parallel.

Moreover, mixed factorial ANOVA test was used to assess whether: i) the domain and task scores of three MoCA forms differed with each other (within-factor main effect); ii) the presentation order of three MoCA versions influenced the scores (between-factor main effect); iii) the MoCA presentation order and cognitive performance on domain and task scores interacted with each other (interaction effect). The Bonferroni test was used for post-hoc analysis.

Finally, Pearson product-moment correlation analysis (r) was performed to explore the degree of association between domain and task scores of three MoCA forms. Effect size for the correlation coefficient was defined by the following criteria: $r < .10$: negligible; $.10 \leq r < .30$: weak; $.30 \leq r < .50$: moderate; $r \geq .50$: strong [31]. The Benjamini-Hochberg [32] procedure was used to control for false discovery rate at the .05 level.

Normative data for MoCA 2 and MoCA 3

To provide normative data of MoCA 2 and 3, we followed the statistical procedures reported in Spinnler and Tognoni [25], and used in Santangelo et al. [22] for MoCA 1. We also assessed convergent validity of total MoCA 2 and MoCA 3 scores by computing their Pearson's correlation coefficients with MMSE score adjusted for age and education.

All analyses were performed using SPSS 18, with $p < .05$ considered statistically significant.

Results

Inter-Form Parallelism

Seventy-eight participants (41 women) were enrolled for comparing the three MoCA versions (mean age= 37.54 years, *SD*= 13.99; mean education= 13.36, *SD*= 4.15; mean MMSE adjusted score= 27.81, *SD*= 1.36); no participant was excluded from analysis on the basis of MMSE score. As for the three-step procedure for assessing the parallelism, Model 1 (equal factor loadings) and Model 2 (equal error variances) showed a tenable fit [χ^2= .07, *df*= 2, *p*= .963, RMSEA= .00 (.00, .97), and χ^2= .96, *df*= 2, *p*= .617, RMSEA= .00 (.00, .67), respectively]. However, Model 3 (equal means) did not show an adequate fit [χ^2= 6.77, *df*= 2, *p*= .033, RMSEA= .17 (.00, .67)], thus suggesting that the three MoCA versions could not be considered as strictly parallel.

Mixed factorial ANOVA test revealed a significant within-factor effect (*F*(27, 46)= 2.80, *p*= .001, η^2_p= .62). Post-hoc analyses revealed significant differences in verbal abstraction, repetition of sentence, and copying of figure task scores. These differences were due to lower scores achieved on the MoCA 1 than on the MoCA 2 and 3. Moreover, the participants obtained lower scores on the MoCA 2's repetition of sentence and copying of figure task, and higher scores in verbal abstraction task in comparison with the MoCA 3 (Table 1).

There was no significant main effect of presentation order (between-factor) [*F*(70, 315)= 0.82, *p*= .830, η^2_p= .15], and no significant interaction effect between presentation order and cognitive performance on domain and task scores [*F*(135, 250)= 0.96, *p*= .600, η^2_p= .341] (data not shown).

As reported in Table 2, the total scores and the corresponding domains of three MoCA versions showed a degree of association from moderate to strong.

Normative data for the MoCA 2 and the MoCA 3

Three-hundred and two (159 women) and 413 (207 women) healthy individuals were enrolled for obtaining normative scores for MoCA 2 and 3, respectively. It was not found any statistically significant difference among the groups of examinees recruited from different regional districts in MoCA 2 or 3 (Supplementary Table 2).

Two participants for MoCA 2 and 4 participants for MoCA 3 were excluded from analysis on the basis of their MMSE scores. The distribution of the samples for age, education, and sex is reported in Table 3. Descriptive statistics for MoCA 2 and 3 total and domain scores are shown in Table 4. The individual regression analyses showed that the square root of education (in years) and the logarithmic transformation of age [log10 (100 - age)] were the most effective in reducing residual variance for all measurements, except for the MoCA 2's memory domain and for the MoCA 3's orientation domain, in which the linear effect of age was the most effective. When partialling out the covariance that each sociodemographic variable shared with the others, the influence of age and education was significant for nearly all domains, except for MoCA 2's language and attention domain (in which age did not influence the performance), and MoCA 3's memory domain (in which education did not influence the performance). The linear effect of the sex was statistically significant only for MoCA 2's and 3's attention domain (Supplementary Table 3).

Grounding on these results, we computed the formulae for exact direct calculation of adjusted MoCA 2 and 3's total and domain scores, including the most suitable transformations of predictor variables (Supplementary Table 4).

As for the MoCA 2, for a sample of 302 participants and using a non-parametric procedure, outer and inner tolerance limits were defined by values corresponding to the 9th and 22th worst observations. As for the MoCA 3, for a sample of 413 participants, outer and inner tolerance limits were defined by values corresponding to the 14th and 28th worst observations (for details Supplementary Table 5). Adjusted MoCA 2 and 3's total and domain scores lower than or equal to the outer tolerance limit (or cut-off point) can be considered abnormal, values higher than the inner tolerance limit indicate a normal performance, while intermediate scores indicate a borderline performance, which in our study was obtained by 4.3 % of MoCA 2 sample participants and by 3.38%of MoCA 3 sample participants. It is important noting that the outer tolerance limits for the memory domain score were negative for MoCA 2 (–0.13) and MoCA 3 (–0.41), thus not allowing any correction.

The score interval corresponding to each ES, the density of observations, and the cumulative frequency of each ES for MoCA 2 and 3 are shown in Table 5.

We computed the correction grid for any combination of age (by 10–year steps), educational level (according to the Italian schooling system), and sex to allow adjustment of raw scores of newly tested individuals (Table 6).

Several adjustment factors computed for the domain scores of visuospatial abilities and executive functions were larger than the respective outer tolerance limits, thus hindering applicability of these domain scores to some combinations of age and education.

For individuals with demographic characteristics not included in the correction grid, it is possible to use the formulae for exact direct calculation of adjusted MoCA 2 and 3 scores shown in Supplementary Table 4, but in this case adjustment factors should be treated with caution.

As for convergent validity, adjusted MMSE total scores [23,24] were positively correlated with adjusted MoCA 2 (r= 0.69, p< .001) and 3 total scores (r= 0.61, p< .001).

Discussion

The main objective of this study was to investigate the parallelism of the three MoCA versions. The results suggested that i) changes in the level of the construct measured by the MoCA yield statistically equivalent changes in all MoCA versions scores (given the equality of factor loadings); ii) the reliability of the MoCA versions is statistically equivalent (given the equality of error variances); iii) some idiosyncratic characteristic to each MoCA version yields non-equivalent mean manifest test scores (given the non-equality of means). The implication of iii) is that an individual with a certain level of global cognitive status might not obtain the same observed score at all the MoCA versions due to specific features of each version. Taken together, these results suggest that the three versions of the MoCA could not be considered as strictly parallel.

A detailed analysis showed significant inter-form differences between some domain and task scores of the three MoCA versions, despite counterbalanced order of presentation. This pattern of results, along with the moderate to strong degree of association between three MoCA versions, suggested that the Italian MoCA 1, 2, and 3 include items covering the same cognitive domains, but with a different level of difficulty. The differences between MoCA forms arose mainly in verbal abstraction, copying of figure, and repetition of sentence tasks. These findings are consistent with the following Lebedeva et al.'s observations on English alternate forms [18]: i) the abstraction items of MoCA 1 were more difficult than the respective alternate items in MoCA 2 and 3; ii) the model to be copied was easier in MoCA 3 than in MoCA 1 and 2. Instead, our findings were not consistent with Lebedeva et al. [18] with respect to sentence repetition, as we found that the sentences used in MoCA 3 were easier to repeat than those included in MoCA 1 and 2. This finding might be due to the translation from English to Italian language, which may have caused inter-form sentence differences in word length or syntactic complexity.

These observations advice clinicians using separate cut-offs and age-, education-, and sex-stratified normative data when using MoCA 2 and 3. To this end, we gathered normative data from a large sample of healthy participants for both alternate MoCA forms.

The Italian MoCA 2 and 3 total mean scores of 24.02 and 24.70 found in our study were lower than those reported in a German study (MoCA 2= 26.44 and MoCA 3= 25.96; [17]) and in a French study (MoCA 2= 25.96 and MoCA 3= 25.80; [16]). These discrepancies might depend on possible sample selection criteria and/or on cultural and linguistic adaptation of the tests, and highlight the necessity to use Italian normative data and cut-offs specifically developed for alternate MoCA forms. The cut-offs for corrected Italian MoCA 2 (17.49) and MoCA 3 (18.34) total score provided in the present study will allow to monitor individuals' cognitive functioning over time avoiding unwanted "learning effects" associated with repeated administration.

As in previous normative studies for MoCA 1 [33-35], we found a significant effect of age and education, but not of sex, for both MoCA 2 and 3 total scores. Similarly, most normative studies have demonstrated that the impact of age and education must be taken into account when evaluating raw scores obtained by old and/or less educated individuals. A clear evidence of this is provided by the huge effect of illiteracy on performance on neuropsychological tests [36], some of which cannot be administered to people without any formal education.

The lack of the effect of sex on MoCA 2 and 3 total score was consistent with Portuguese [33], Japanese [35], and Italian normative studies on MoCA 1 [20,22].

Beyond providing a total score, alternate MoCA versions allow to obtain measures of main cognitive domains commonly related to both cortical and subcortical dementias [1]. We provided normative data for all cognitive domains and evaluated the possible effects of sociodemographic variables on them, concluding that the educational level and age generally influenced the cognitive performances. This trend was not present in MoCA 3's memory domain (not influenced by education), and in MoCA 2's language and attention domains (not affected by age). These differences may be related to differences in the items covering the same cognitive domains, and strongly confirm the importance of using solid and specific normative data.

The effect of sex on MoCA 2 and 3's attention domain was consistent with previous evidence on MoCA 1 [22], generally showing a male advantage. This finding was present also in another Italian normative study on a paper-and-pencil digit cancellation test (attentional matrices; [25]), though there are divergent empirical findings on this issue (e.g., [37,38]).

Noteworthy, the use of memory domain score seems to be impeded in MoCA 2 and 3 because of the presence of a negative cut-off, similarly to what observed for Italian MoCA 1 [22]. Considering the statistical procedure described above, a negative cut-off is possible only when a percentage higher than 5% of the normative sample achieves a negative adjusted score (i.e., participants receiving a negative correction factor greater in absolute value than their raw score). This pattern would suggest the introduction of some changes in the memory domain score of future versions of the MoCA.

Our findings about correlation between MoCA 2 and 3 and MMSE scores indicated a strong convergent validity between these instruments in healthy individuals, consistent with the idea that MMSE and MoCA share the same construct (i.e., global cognitive functioning). However, it should be reminded that MoCA meets the screening test criteria for the detection of MCI better than MMSE [39].

It is important to acknowledge that the present study has limitations. First, our sample size was rather small to verify the Inter-Form Parallelism, as recommended by Raykov et al.'s [30]. Indeed, the three-step procedure for examining parallelism of three measures would require that each step is verified on different subsamples, whereas we used the same sample for each step in order to preserve sufficient statistical power for parameter estimations. However, to verify whether the present sample size could make our inter-form parallelism analysis unreliable, we run a power analysis on an unconstrained measurement model (all loadings and error variances free to vary, according to Muthén and Muthén, [40]). The results of this analysis (Supplementary Table 6) suggested that a sample of at least 50 participants was sufficiently large for allowing relatively unbiased parameter estimates.

Second, we enrolled the overall sample in Southern Italy and this sampling strategy did not allow us to detect possible regional differences in MoCA scores, prompting future studies to explore this issue in depth. However, in the present paper we did not detect differences as a function of participants' districts. Moreover, comparing raw data from Italian normative studies carried out on the same neuropsychological test in different regions, we observed marginal effect sizes of the differences between studies; e.g., Frontal Assessment Battery [Northern [26] vs. Southern Italy [41]), 16.10±1.80 vs. 15.29±2.77, Cohen's *d*= 0.35] or MoCA 1 [Northern [20] vs. Southern Italy [22], 23.28±3.22 vs. 21.98±4.22, Cohen's *d*= 0.34]. Third, we did not exclude individuals affected by chronic vascular or metabolic illnesses, which are very frequent in the aged people. These enrolment criteria choices might have contributed to age-related decrease in MoCA scores, but are shared with most Italian normative studies (e.g., [42-44]). We conformed to this practice, also for the sake of consistency among Italian normative data.

In conclusion, the present study demonstrates that Italian alternate MoCA forms show differences in some domain scores, as recently reported in other languages [17]. Since MoCA is particularly suited for detection of MCI [38] and encompasses tasks tapping executive abilities [11], it is important to adopt alternate versions of the test to assess changes in general cognitive abilities over time reliably. No test for general cognitive abilities other than MoCA has alternate forms available in Italy. The present study provided the first Italian normative data for MoCA 2 and 3 and allowing their interchangeable use in clinical and research longitudinal studies [17], taking into account the different influence of sociodemographic variables on alternate MoCA total and domain scores. Future studies should be oriented to determine, both for MoCA 2 and MoCA 3, the cut-offs scores distinguishing normal individuals from those affected by mild cognitive impairment or dementia.

Conflict of interest. The authors have no conflict of interest to disclose.

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Table 1. Descriptive statistics of three Montreal Cognitive Assessment (MoCA) versions and within-factor effect analyses (n= 78).

	MoCA 1	*MoCA 2*	*MoCA 3*	*p*	Adj-p	η^2_p	*MoCA 1* vs. *MoCA 2* (*p*)
Executive functions	2.67 (1.10)	3.28 (0.86)	3.13 (0.81)	<.001	**<.001**	.19	**<.001**
Trail Making Task	0.76 (0.43)	0.86 (0.35)	0.82 (0.38)	.096	.178	.03	–
Phonemic fluency	0.78 (0.41)	0.74 (0.43)	0.85 (0.36)	.064	.139	.03	–
Verbal abstraction	1.13 (0.74)	1.68 (0.59)	1.46 (0.59)	<.001	**<.001**	.24	**<.001**
Language	5.31 (0.77)	5.19 (0.89)	5.53 (0.69)	.003	**.012**	.07	.252
Naming	2.87 (0.33)	2.83 (0.37)	2.86 (0.35)	.758	.758	.00	–
Repetition of sentence	1.64 (0.50)	1.61 (0.54)	1.82 (0.44)	.012	**.034**	.05	.748
Phonemic fluency (as above)	–	–	–	–	–	–	–
Visuospatial abilities	3.29 (0.83)	3.28 (0.83)	3.47 (0.65)	.020	.051	.05	–
Clock-drawing	2.44 (0.67)	2.52 (0.59)	2.5 (0.63)	.383	.442	.01	–
Copying of figure	0.85 (0.36)	0.77 (0.42)	0.99 (0.11)	<.001	**<.001**	.14	.083
Attention	5.46 (0.71)	5.44 (0.84)	5.29 (0.92)	.182	.230	.02	–
Sustained attention[a]	–	–	–	–	–	–	–
Serial subtraction	2.71 (0.51)	2.63 (0.64)	2.67 (0.63)	.585	.627	.01	–
Forward span	0.92 (0.26)	0.95 (0.22)	0.86 (0.35)	.114	.178	.03	–
Backward span	0.83 (0.37)	0.86 (0.35)	0.77 (0.42)	.184	.230	.02	–
Memory (Delayed recall)	1.83 (1.53)	2.01 (1.60)	1.62 (1.46)	.119	.178	.03	–
Orientation[a]	–	–	–	–	–	–	–

Note. MoCA: Montreal Cognitive Assessment; a, this subtest is equal for the three alternate MoCA versions; Adj-*p* represents *p* value corrected for Benjamini-Hochberg procedure; η^2_p= partial eta squared; Bonferroni method (.05/3 =.017) was used for post hoc analyses; descriptive statistics are reported as mean (standard deviation) and significant differences are shown in **bold**.

Table 2. Pearson product-moment correlations between the total score and domain subscores of the three Montreal Cognitive Assessment (MoCA) versions.

	1	2	3	4	5	6	7	8	9	10	11	12	13
MoCA 1													
1. Total score													
2. Executive functions	0.61**												
3. Language	0.60**	0.44**											
4. Visuospatial abilities	0.53**	0.17	0.01										
5. Attention	0.47**	0.08	0.18	0.37**									
6. Orientation	−0.06	−0.09	0.11	−0.12	−0.20								
7. Memory	0.76**	0.28*	0.38**	0.21	0.14	−0.19							
MoCA 2													
8. Total score	0.64**	0.29*	0.37**	0.30*	0.23	0.06	0.55**						
9. Executive functions	0.40**	0.54**	0.46**	−0.04	−0.45	0.00	0.29*	0.47**					
10. Language	0.29*	0.25	0.45**	−0.07	−0.12	−0.07	0.38**	0.53**	0.41**				
11. Visuospatial abilities	0.34**	0.04	−0.03	0.60**	0.30*	−0.12	0.17	0.47**	−0.05	0.01			
12. Attention	0.29*	0.04	0.10	0.16	0.45**	−0.09	0.16	0.45**	0.18	0.07	0.26*		
13. Orientation	−0.06	−0.09	0.11	−0.12	−0.20	1.00**	−0.19	0.06	0.00	−0.07	−0.12	−0.09	
14. Memory	0.47**	0.14	0.18	0.22	0.10	0.07	0.51**	0.76**	0.12	0.28*	0.22	0.01	0.07
MoCA 3													
15. Total score	0.63**	0.30*	0.39**	0.44**	0.37**	0.00	0.42**	0.67**	0.20	0.38**	0.46**	0.34**	0.00
16. Executive functions	0.50**	0.52**	0.51**	0.07	0.29*	−0.02	0.26*	0.38**	0.44**	0.28*	0.13	0.20	−0.02
17. Language	0.25	0.23	0.36**	0.04	0.10	−0.06	0.16	0.25*	0.28*	0.39**	−0.01	−0.04	−0.06
18. Visuospatial abilities	0.36**	0.04	0.04	0.73**	0.16	−0.26*	0.22	0.30*	0.01	0.12	0.60**	0.09	−0.26*
19. Attention	0.43**	0.16	0.14	0.32*	0.51**	−0.23	0.28*	0.43*	−0.05	0.21	0.37**	0.47**	−0.23
20. Orientation	−0.06	−0.09	0.11	−0.12	−0.20	1.00**	−0.19	0.06	0.00	−0.07	−0.12	−0.09	1.00**
21. Memory	0.31*	0.15	0.18	0.24	0.08	0.04	0.25	0.43**	0.05	0.22	0.28*	0.19	0.04

Note. **$p < .01$, *$p < .05$ *after Benjamini-Hochberg correction.*

Table 3. Distribution of the normative samples according to age, education, and sex.

	Age, years							Total
	20 – 29	30 - 39	40 - 49	50 - 59	60 – 69	70 – 79	80 – 89	
MoCA 2								
Education level, years								
1 – 5								
men	–	–	4	4	6	5	8	27
women	–	–	5	6	8	8	7	34
6 – 8								
men	2	3	10	6	5	3	1	30
women	2	4	10	10	3	7	2	38
9 – 13								
men	7	6	10	15	6	3	1	48
women	7	5	10	15	6	2	1	46
>13								
men	6	5	5	6	8	6	2	38
women	9	4	6	9	5	6	2	41
Total								
men	15	14	29	31	25	17	12	143
women	18	13	31	40	22	23	12	159
MoCA 3								
Education level, years								
1 – 5								
men	–	–	1	2	5	9	5	22
women	–	–	3	2	6	10	10	31
6 – 8								
men	3	2	5	5	9	9	3	36
women	2	2	4	13	8	11	2	42
9 – 13								
men	14	11	7	14	14	7	2	69
women	11	6	12	14	14	6	2	65
>13								
men	16	15	5	14	18	8	3	79
women	16	11	6	14	15	6	1	69
Total								
men	33	28	18	35	46	33	13	206
women	29	19	25	43	43	33	15	207

Table 4. Descriptive statistics.

	M	*SD*	*Mdn*	Range (min – max)
MoCA 2 (*n*= 302)				
Age, years	53.43	16.87	53	20 – 87
Education, years	11.02	4.72	12	1 – 18
MMSE total score*	28.34	1.92	29	22 – 30
MMSE adjusted score	28.00	1.43	28	24 – 30
MoCA total score*	24.02	4.00	25	6 – 30
*Cognitive domains:**				
Executive functions	3.07	1.13	3	0 – 4
Language	4.83	1.16	5	0 – 6
Visuospatial abilities	2.79	1.08	3	0 – 4
Attention	5.39	0.99	6	1 – 6
Orientation	5.80	0.49	6	3 – 6
Memory	2.81	1.57	3	0 – 5
MoCA 3 (*n*= 413)				
Age, years	54.56	18.64	56	18 – 89
Education, years	12.12	4.37	13	2 – 18
MMSE total score*	28.90	1.55	30	22 – 30
MMSE adjusted score	28.76	1.59	30	23.74 – 30
MoCA total score*	24.70	3.67	25	12 – 30
*Cognitive domains:**				
Executive functions	3.28	0.91	4	0 – 4
Language	5.34	0.90	6	2 – 6
Visuospatial abilities	2.95	0.96	3	0 – 4
Attention	5.38	1.03	6	0 – 6
Orientation	5.93	0.29	6	3 – 6
Memory	2.48	1.76	2	0 – 5

Note. *M*, Mean; *SD*, Standard Deviation; *Mdn*, Median; *expressed as raw score; MoCA, Montreal Cognitive Assessment; MMSE, Mini Mental State Examination.

Table 5. Equivalent scores (ES) for adjusted total and domain scores.

ES	Interval	Cumulative frequency	Density
MoCA 2			
Total score			
0	≤17.49	9	9
1	17.50–19.93	32	23
2	19.94–22.41	80	48
3	22.42–24.56	151	71
4	>24.56	302	151
Executive functions			
0	≤0.93	9	9
1	0.94–1.83	32	23
2	1.84–2.61	80	48
3	2.62–3.21	151	71
4	>3.21	302	151
Language			
0	≤2.63	12	12
1	2.64–3.60	37	25
2	3.61–4.25	84	47
3	4.26–4.86	151	67
4	>4.86	302	151
Visuospatial abilities			
0	≤1.05	9	9
1	1.06–1.61	32	23
2	1.62–2.16	80	48
3	2.17–2.91	151	71
4	>2.91	302	151
Attention			
0	≤2.81	9	9
1	2.82–4.10	32	23
2	4.11–5.10	80	48
3	5.11–5.67	151	71
4	>5.67	302	151
Orientation			
0	≤4.36	9	9
1	4.37–5.11	32	23
2	5.12–5.79	80	48
3	5.80–5.92	151	71
4	>5.92	302	151
MoCA 3			
Total score			
0	≤18.34	14	14
1	18.35–21.00	46	32
2	21.01–22.99	112	66
3	23.00–25.00	207	95
4	>25.00	413	206
Executive functions			
0	≤1.62	14	14
1	1.63–2.19	46	32
2	2.20–2.84	112	66
3	2.85–3.43	207	95
4	>3.43	413	206

To be continued

Table 5. Continued.

ES	Interval	Cumulative frequency	Density
MoCA 3			
Language			
0	≤3.51	14	14
1	3.52–4.38	46	32
2	4.39–4.94	112	66
3	4.95–5.55	207	95
4	>5.55	413	206
Visuospatial abilities			
0	≤1.16	14	14
1	1.17–1.79	46	32
2	1.80–2.42	112	66
3	2.43–3.07	207	95
4	>3.07	413	206
Attention			
0	≤2.98	14	14
1	2.99–4.29	46	32
2	4.30–5.19	112	66
3	5.20–5.59	207	95
4	>5.59	413	206
Orientation			
0	≤5.03	15	15
1	5.04–5.93	48	33
2	5.94	113	65
3	5.95–5.98	207	94
4	>5.98	413	206

Table 6. Correction grid for raw total and domain scores of alternate Montreal Cognitive Assessment (MoCA) versions.

Education, years	Age, years						
	20 – 29	30 – 39	40 – 49	50 – 59	60 – 69	70 – 79	80 – 89
MoCA 2							
Total score							
1 – 5	3.81*	4.19*	4.64	5.17	5.84	6.73	8.09
6 – 8	0.06	0.43	0.88	1.41	2.08	2.97	4.33
9 – 13	−1.69	−1.31	−0.86	−0.33	0.33	1.22	2.58
>13	−3.33	−2.95	−2.50	−1.97	−1.30	−0.41	0.94
Executive functions							
1 – 5	■	■	■	■	■	■	■
6 – 8	0.19	0.25	0.33	0.43	0.55	0.71	■
9 – 13	−0.32	−0.25	−0.17	−0.08	0.03	0.19	0.44
>13	−0.81	−0.74	−0.66	−0.56	−0.44	−0.28	−0.04
Language							
1 – 5	1.27*	1.27*	1.27	1.27	1.27	1.27	1.27
6 – 8	0.37	0.37	0.37	0.37	0.37	0.37	0.37
9 – 13	−0.04	−0.04	−0.04	−0.04	−0.04	−0.04	−0.04
>13	−0.44	−0.44	−0.44	−0.44	−0.44	−0.44	−0.44
Visuospatial abilities							
1 – 5	1.01*	■	■	■	■	■	■
6 – 8	0.05	0.13	0.24	0.36	0.52	0.72	1.04
9 – 13	−0.39	−0.30	−0.20	−0.08	0.07	0.27	0.59
>13	−0.81	−0.72	−0.62	−0.50	−0.34	−0.14	0.17
Attention (male)							
1 – 5	0.73*	0.73*	0.73	0.73	0.73	0.73	0.73
6 – 8	0.09	0.09	0.09	0.09	0.09	0.09	0.09
9 – 13	−0.19	−0.19	−0.19	−0.19	−0.19	−0.19	−0.19
>13	−0.47	−0.47	−0.47	−0.47	−0.47	−0.47	−0.47
Attention (female)							
1 – 5	1.04*	1.04*	1.04	1.04	1.04	1.04	1.04
6 – 8	0.40	0.40	0.40	0.40	0.40	0.40	0.40
9 – 13	0.11	0.11	0.11	0.11	0.11	0.11	0.11
>13	−0.16	−0.16	−0.16	−0.16	−0.16	−0.16	−0.16
Orientation							
1 – 5	0.17*	0.21*	0.25	0.30	0.37	0.45	0.58
6 – 8	−0.04	−0.01	0.03	0.08	0.14	0.22	0.35
9 – 13	−0.15	−0.11	−0.07	−0.02	0.03	0.12	0.25
>13	−0.25	−0.21	−0.17	−0.12	-0.06	0.02	0.15
MoCA 3							
Total score							
1 – 5	2.19*	2.64*	3.17	3.80	4.6	5.66	7.27
6 – 8	−0.46	−0.01	0.51	1.14	1.93	3.00	4.61
9 – 13	−1.70	−1.25	−0.72	−0.09	0.69	1.75	3.37
>13	−2.86	−2.41	−1.88	−1.25	−0.46	0.60	2.21
Executive functions							
1 – 5	0.69*	0.77*	0.86	0.97	1.11	1.29	1.57
6 – 8	0.02	0.10	0.19	0.30	0.44	0.63	0.91
9 – 13	−0.28	−0.20	−0.11	0.00	0.13	0.31	0.60
>13	−0.57	−0.49	−0.40	−0.29	−0.15	0.03	0.31

To be continued

Table 6. Continued.

	Age, years						
	20 - 29	30 - 39	40 - 49	50 - 59	60 - 69	70 - 79	80 - 89
MoCA 3							
Language							
1 – 5	0.98*	1.02*	1.07	1.13	1.21	1.32	1.48
6 – 8	0.22	0.26	0.31	0.38	0.45	0.56	0.72
9 – 13	−0.13	−0.08	−0.03	0.02	0.10	0.21	0.36
>13	−0.46	−0.41	−0.36	−0.30	−0.22	−0.12	0.03
Visuospatial abilities							
1 - 5	0.44*	0.52*	0.62	0.74	0.89	1.08	■
6 - 8	−0.07	0.01	0.10	0.22	0.37	0.56	0.86
9 - 13	−0.31	−0.23	−0.13	−0.01	0.13	0.32	0.62
>13	−0.53	−0.45	−0.35	−0.24	−0.09	0.10	0.40
Attention (male)							
1 - 5	0.53*	0.60*	0.68	0.78	0.90	1.07	1.32
6 - 8	−0.08	−0.01	0.06	0.16	0.28	0.45	0.70
9 - 13	−0.37	−0.30	−0.22	−0.12	0.00	0.16	0.42
>13	−0.64	−0.57	−0.49	−0.39	−0.26	−0.10	0.15
Attention (female)							
1 - 5	0.77*	0.84*	0.93	1.03	1.15	1.32	1.57
6 - 8	0.15	0.23	0.31	0.41	0.53	0.70	0.95
9 - 13	−0.12	−0.05	0.02	0.12	0.24	0.41	0.66
>13	−0.39	−0.32	−0.24	−0.14	−0.02	0.14	0.39
Orientation							
1 - 5	0.08*	0.10*	0.12	0.14	0.16	0.18	0.20
6 - 8	−0.01	0.00	0.02	0.04	0.06	0.08	0.10
9 - 13	−0.05	−0.03	−0.01	0.00	0.02	0.04	0.06
>13	−0.09	−0.07	−0.05	−0.03	−0.01	0.00	0.02

Note. Values marked by the asterisk (*) should be taken cautiously because they were obtained by extrapolation from the formulas given in Supplementary Table 4; (■) test is not applicable to this group.