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Bridging Cognitive Screening Tests in Neurological Disorders: A cross-walk between the s-MoCA and MMSE

David R. Roalf, Ph.D.^{1,*}, Tyler M. Moore, Ph.D.¹, Dawn Mechanic-Hamilton^{2,3}, David A. Wolk, M.D.^{2,3}, Steven E. Arnold, M.D., Ph.D.⁶, Daniel A. Weintraub, M.D.^{1,2,4,5}, and Paul J. Moberg, Ph.D.^{1,2,3}

¹Department of Psychiatry, University of Pennsylvania Perelman School of Medicine, Philadelphia, Philadelphia, PA, 19104

²Department of Neurology, University of Pennsylvania Perelman School of Medicine, Philadelphia, Philadelphia, PA, 19104

³Alzheimer's Disease Center, University of Pennsylvania Perelman School of Medicine, Philadelphia, Philadelphia, PA, 19104

⁴Udall Center for Parkinson's Research, University of Pennsylvania Perelman School of Medicine, Philadelphia, Philadelphia, PA, 19104

Please address correspondence to: David R. Roalf, Ph.D., Assistant Professor of Behavioral Neuroscience, Department of Psychiatry, Neuropsychiatry Section, Brain Behavior Laboratory, 10th Floor, Gates Building, Hospital of the University of Pennsylvania, Philadelphia, PA 19104, roalf@upenn.edu.

*denotes equal contribution

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David R. Roalf: drafting/revising the manuscript, study concept or design, analysis or interpretation of data, accepts responsibility for conduct of research and will give final approval, acquisition of data, statistical analysis, study supervision. Dr. Roalf takes the role of Principal Investigator, has access to all of the data and takes responsibility for the data, accuracy of data analysis and conduct of the research. Dr. Roalf acknowledges and shares equal contribution as first author with Dr. Moore. Dr. Roalf will serve as the Corresponding Author.

Tyler M. Moore: drafting/revising the manuscript, study concept or design, analysis or interpretation of data, accepts responsibility for conduct of research and will give final approval, acquisition of data, statistical analysis.

Dawn Mechanic-Hamilton: revising the manuscript, study concept or design, accepts responsibility for conduct of research and will give final approval, study supervision.

David Wolk: study concept or design, accepts responsibility for conduct of research and will give final approval, study supervision, obtaining funding.

Steven Arnold: study concept or design, accepts responsibility for conduct of research and will give final approval, study supervision, obtaining funding.

Daniel Weintraub: study concept or design, accepts responsibility for conduct of research and will give final approval, study supervision, obtaining funding.

Paul J. Moberg: drafting/revising the manuscript, study concept or design, analysis or interpretation of data, accepts responsibility for conduct of research and will give final approval, study supervision.

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⁵Parkinson's Disease Research, Education and Clinical Center (PADRECC) at the Philadelphia VA Medical Center, Philadelphia, Philadelphia, PA, 19104

⁶Department of Neurology of Massachusetts General Hospital, Harvard University, Boston, MA 02114 U.S.A

Abstract

INTRODUCTION—To provide a cross-walk between the recently proposed short MoCA (s-MoCA) and MMSE within a clinical cohort.

METHOD—791 participants, with and without neurological conditions, received both the Mini-Mental State Examination (MMSE) and the Montreal Cognitive Assessment (MoCA) at the same visit. s-MoCA scores were calculated and equipercetile equating was used to create a cross-walk between the s-MoCA and MMSE

RESULTS—As expected, s-MoCA scores were highly correlated (Pearson $r=0.82$, $p<0.001$) with MMSE scores. s-MoCA scores correctly classified 85% of healthy older adults and 91% of individuals with neurological conditions that impair cognition. In addition, we provide an easy to use table that enables the conversion of s-MoCA score to MMSE scores.

DISCUSSION—The s-MoCA is quick to administer, provides high sensitivity and specificity for cognitive impairment, and now can be compared directly to the MMSE.

Keywords

s-MoCA; MMSE; cognitive screening; test equating; brief cognitive test

INTRODUCTION

The need for adequate and effective cognitive screening is essential given the rapid growth of the elderly population and the increasing prevalence of Alzheimer's disease (AD) and related disorders. Unfortunately, those with, or developing, dementia often go undiagnosed and many are not even evaluated [1]. In fact, upwards of 40 percent of older adults with cognitive impairment are often not identified as impaired [2]. The failure to assess cognitive abilities likely hampers the diagnosis and treatment of neurodegenerative and non-neurodegenerative dementia, and may significantly affect patients' and family members' wellbeing. Yet, most current memory and cognitive screening measures remain too lengthy for regular use in community and primary care settings. Consequently, despite widespread attention given to the growing economic costs of treating and caring for people with AD and other neurodegenerative diseases [3], the availability of time and cost-effective cognitive screening tests are limited. In order to serve this demand, well-validated and efficient cognitive screening tests are needed for administration as part of routine clinical visits and check-ups[4].

Many cognitive screening measures exist; the Mini-Mental State Examination (MMSE) [5] and Montreal Cognitive Assessment (MoCA) [6] are two of the most common. Recent work[7] confirms and extends prior findings on the diagnostic utility of the MMSE and MoCA. While the MMSE has a long history of use in clinical and research settings for the

assessment and monitoring of acute neurocognitive impairments, it has limited utility in detecting subtle changes in cognition that may signal pending impairment in at-risk individuals [8, 9]. In addition, the MMSE has large ceiling effects [10]—even when corrected for education [11], and relatively poor accuracy in the identification of patients with mild cognitive impairment or mild AD [12]. The MoCA overcomes some, but not all, of the limitations of the MMSE, and evidence is accumulating that the MoCA may eventually supplant the MMSE as the gold-standard in cognitive screening for AD dementia [7, 13]. Specifically, the MoCA includes more robust measures of visuospatial and executive function [6], which likely reduces ceiling and practice effects, but enhances the potential for floor effects. Indeed, comparisons of these two measures find that the MoCA has better sensitivity and specificity in AD, Mild Cognitive Impairment (MCI) [7] and Parkinson's disease (PD) [13]. Thus, the MoCA may be most informative when attempting to differentiate mild forms of dementia from typical age-related decline. However, one of the most significant limitations of the MoCA is the 10–15 minute administration time.

Recently, using a scale-shortening method first described in [14], we established and validated a short form of the standard MoCA (s-MoCA) composed of 8 items, which takes approximately 5 minutes to administer [15]. Item response theory and computerized adaptive testing simulation were used to derive the s-MoCA in 1,850 well-characterized community-dwelling individuals with and without neurodegenerative disease. The s-MoCA was highly correlated with the original MoCA, exhibited robust diagnostic classification, and cross-validation procedures substantiated the selected items. Thus, the s-MoCA is highly comparable to the standard MoCA, generalizable to healthy individuals and those with neurological conditions and, most importantly, can be administered more quickly.

Yet, we acknowledge that adoption of the s-MoCA within the primary care setting, neurology clinics and specialized research settings may be difficult given the historical importance and ubiquity of the MMSE in clinimetrics, research programs and randomized clinical trials. Thus, in the current report we provide a straightforward method for converting s-MoCA scores to MMSE scores. The results will facilitate the adoption of the s-MoCA within the clinic by providing continuity in cognitive assessment scores in the clinic and comparability of data in the research setting that will ensure valid longitudinal assessment.

METHODS

Participants

All participants (n=791) were recruited from the Penn Memory Center and Clinical Core of the University of Pennsylvania's Alzheimer's Disease Center. One-hundred thirty-eight healthy older adults (HOA) and 653 individuals with a neurological condition were assessed. AD (n=340) and MCI (n=109) diagnoses accounted for the majority of individuals. To increase generalizability of equated scores, participants with the following neurological conditions were also included: frontotemporal dementia (n=15), corticobasal syndrome (n=5), dementia with Lewy Bodies (n=25), dementia, unspecified (n=19), hydrocephalus (n=26), multiple clinical diagnoses (n=16), indeterminate neurological condition (n=56), PD (n=2), Posterior Cortical Atrophy (n=4), Primary Progressive Aphasia (7), progressive supranuclear palsy (n=2), psychiatric illness (n=13), traumatic Brain Injury (n=2), and

vascular dementia (n=12). Note that individuals with multiple clinical diagnoses were individuals with at least two neurological or psychiatric clinical diagnoses. Clinical assessments included history, physical, and neurological examinations conducted by experienced clinicians, including the review of neuroimaging, psychometric and laboratory data. A consensus diagnosis was established using standardized clinical criteria for AD, MCI, or other neurological or psychiatric conditions presenting with cognitive impairment [16–18]. Additional details on subject recruitment and evaluation have been previously published [7, 15]

All 791 participants were administered the MMSE and MoCA during the same visit. The MMSE result was available during consensus diagnosis, but the MoCA was not. Informed consent for the use of all data was obtained from all persons, in accord with The University of Pennsylvania Institutional Review Board.

s-MoCA scores

Combining sophisticated approaches of item response theory and computerized adaptive testing analytics in 1,850 individuals, we previously established an approach for generating s-MoCA scores [15]. This short form consists of 8-items from the original MoCA, including the following items: 1) clock draw, 2) serial subtraction, 3) orientation (place), 4) recall, 5) abstraction (watch), 6) naming (rhino), 7) trail-making, and 8) language fluency (See [15] Supplemental Material). The score ranges from 0–16, is comparable to the standard MoCA and outperforms another short version of the MoCA, which was derived from an AD/MCI sample only[19]. Correct responses on these 8 items are summed to generate the total s-MoCA score.

Statistical Analysis

Between-group comparisons of MMSE and s-MoCA scores were performed using independent sample t-tests. s-MoCA scores were equated to MMSE scores using the equipercentile equating method [7, 20], which has been used to equate numerous standardized tests [13, 15, 21]. This statistical method allows for the determination of comparable test scores from two different measures on the basis of their corresponding percentile ranks. The advantage of the equipercentile equating method is that the equated scores always fall within the range of possible scores. Log-linear smoothing was applied to avoid an irregular distribution of scores [22]. Polychoric correlations between items were used to estimate internal consistency of the s-MoCA. Equipercentile equating with log-linear smoothing was performed using the ‘equate’ library in the R statistical package (v3.2.2. “Fire Safety”).

RESULTS

Demographic characteristics and test performance are displayed in Table 1A. Individual performance on the s-MoCA encompassed all possible scores from 0 to 16. s-MoCA and MMSE scores were highly correlated (Pearson $r=0.82$, $p<.001$). On average, HOA scored significantly higher on both the MMSE = 29.34 (0.92) and s-MoCA = 13.53 (1.93) relative to individuals with any type of neurological disorder—MMSE = 21.77 (6.27) and s-MoCA =

6.23 (3.81), and higher than individuals with MCI—MMSE = 26.09 (3.34) and s-MoCA = 8.64(2.85) or AD — MMSE =19.53 (5.81) and s-MoCA = 4.79 (3.22). For comparison, standard MoCA scores are presented in Table 1A and Supplemental Figure 3. Those with neurological conditions (Age = 74.36 (8.88) were slightly, but significantly older than healthy older adults (Age = 70.29 (8.98); $t(790)=-4.71$, $p=1.26\times 10^{-6}$). Internal consistency of the items of the s-MoCA was high, Cronbach's alpha =0.90 and Clinical Dementia Rating (CDR) Sum of Boxes scores were inversely associated with s-MoCA scores (Pearson $r(677)=-0.74$, $p<2.20\times 10^{-16}$). Sensitivity, specificity, Youden Index, positive and negative predictive value, clinical cut-off score and classification accuracy are presented in Table 1B. As expected, the s-MoCA had high sensitivity and specificity and performed similarly to the full MoCA—while typically outperforming the MMSE-- at identifying individuals with cognitive dysfunction. s-MoCA scores correctly classified 90% of individuals when differentiating individuals with neurological conditions from HOA, which was 2% better than performance of the standard MoCA and 7% better than the MMSE.

A plot of the equipercenile equivalent scores on the MMSE and s-MoCA is presented in Figure 1A. For example, an s-MoCA score=7 is equivalent to an MMSE score=25, as both of these scores fall at the 50th percentile within a sample with a wide range of cognitive impairment, including healthy individuals. Figure 1B provides the mean, median and range for MMSE scores for each score on the s-MoCA, and their respective equipercenile equivalent score on the MMSE. Equated scores for only AD dementia, including MCI are presented in Supplemental Figure 2 and Supplemental Table 1.

DISCUSSION

Early and accurate detection of cognitive impairment in older adults that indicates transition to AD dementia can enhance clinical management as well as lead to better understanding of individual differences in disease progression. Thus, there is a need for time- and cost-effective approaches that allow for the identification of prodromal disease stages, particularly in primary care clinics. As early detection becomes more necessary, well-validated and brief measures of cognitive performance, such as the s-MoCA, can provide clinicians an efficient tool with which to routinely screen patients and efficiently identify those in need of specialized care or more comprehensive neuropsychological assessment. Here, we show that in general the s-MoCA outperforms that MMSE in identifying older individuals with mild cognitive dysfunction, provide additional evidence of the clinical utility of the s-MoCA and present a cross-walk between s-MoCA and MMSE scores. This cross-walk will enable the widely recognized cut-off scores on the MMSE to be reliably linked with scores on the s-MoCA.

We believe that the s-MoCA is an ideal screening tool for physicians, nurse practitioners and physician assistants in primary care practice, as these practitioners are often the first to hear a patient's complaints. We are encouraged that the s-MoCA works as well as the full MoCA and in many instances better than the MMSE, in particular at differentiating MCI from normal healthy aging. In this respect the s-MoCA can provide a much-needed quick screen in the primary care setting. The s-MoCA can be quite useful in this setting since the assessment of cognitive functioning is a required element of the Medicare Annual Wellness

visit [23]. Other early screening questionnaires or tests that are available and recommended by the National Institute of Aging including the General Practitioner Assessment of Cognition (GPCOG), the Mini-Cog and the Memory Impairment Screen (MIS)[23]. However, the s-MoCA expands upon these by covering more cognitive domains, and thus may have broader appeal and utility. We add the s-MoCA to the clinician's toolbox for consideration as a quick and reliable cognitive screen that meets many of the attributes considered necessary for routine use in primary care settings and that can now be directly compared to MMSE performance.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Research in Context

1. **Systematic review:** The need for adequate, effective and efficient cognitive screening is essential given the rapid growth of the elderly population and the prevalence of Alzheimer’s disease and other cognitive disorders. Unfortunately, dementia screening in the community setting is often overlooked since cognitive assessments are time consuming; this hampers dementia diagnosis and treatment.
2. **Interpretation:** The short form MoCA (s-MoCA) outperforms the MMSE, indicating more time efficient cognitive screening inventories can be implemented in clinical and research settings.
3. **Future directions:** We hope that prospective studies of dementia will implement the s-MoCA, as this shorten version provides an efficient, valid estimate of cognitive function. We are eager to see the s-MoCA implemented in primary care settings as these practitioners are often the first to hear patient’s complaints, and we believe it can aid in the assessment of cognitive functioning—a required element of the Medicare Annual Wellness visit.

Figure 1A

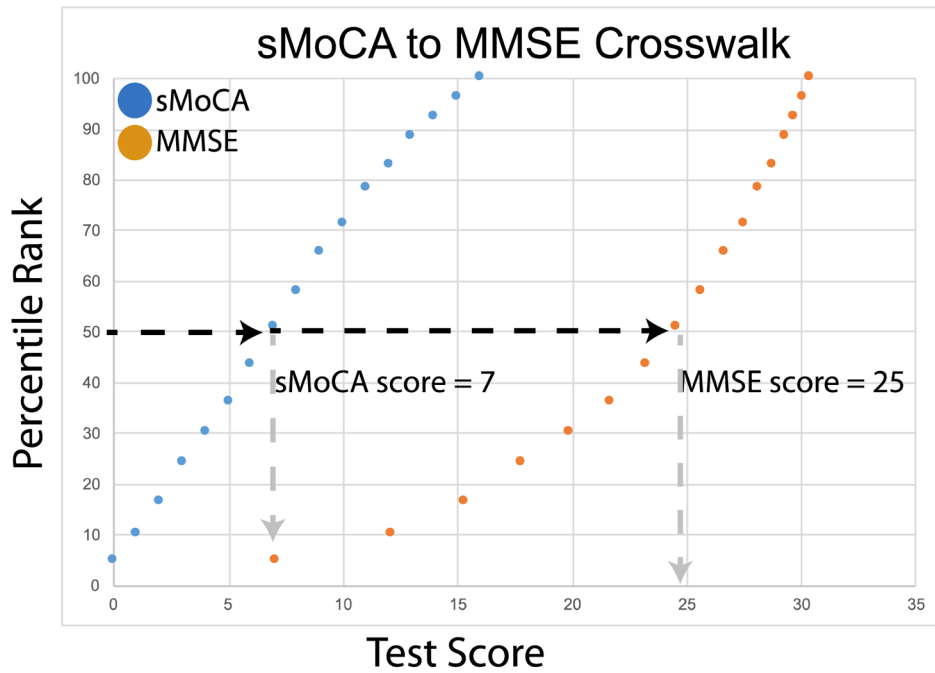


Figure 1B

sMoCA score	Equivalent MMSE score	Average MMSE score Mean (+/- SD)	Median MMSE score	MMSE range	N
0	7	9 (5)	9	0-21	37
1	12	13 (5)	13	2-24	44
2	15	16 (4)	16	6-23	50
3	18	19 (3)	19	13-25	61
4	20	21 (4)	21	10-29	46
5	22	21 (3)	21	14-28	48
6	23	23 (3)	23	16-29	57
7	25	24 (3)	23	14-30	59
8	26	25 (3)	25	17-30	57
9	27	26 (3)	26	19-30	59
10	27	27 (2)	27	21-30	46
11	28	28 (2)	28	23-30	54
12	29	28 (1)	28	25-30	37
13	29	29 (1)	30	25-30	45
14	30	29 (1)	30	24-30	31
15	30	29 (1)	30	27-30	29
16	30	30 (1)	30	28-30	31

Figure 1. Equipercentile equating of the sMoCA and MMSE> Corresponding test scores and percentile ranks allow for conversion of sMoCA scores to MMSE scores. For example, a

sMoCA score of 7 (50th percentile) is equivalent to a MMSE score of 25 (50th percentile).

All neurological conditions were included in the cross-walk.

Figure 1A. A plot of the equipercntile equivalent scores on the MMSE and s-MoCA. As an example, a score of 7 on the s-MoCA is equivalent to a score of 25 on the MMSE, as both of these scores fall at the 50th percentile within a sample with a wide range of cognitive impairment, including healthy individuals.

Figure 1B. Equivalent, average, median and the range of MMSE scores are shown for each possible score on the s-MoCA. Equivalent MMSE scores were generated using equipercntile equating method. The number of individuals that achieved a given s-MoCA score is shown in the final column.

Table 1A

Participant demographics and cognitive screening performance.

	N	Age M (SD) years	Gender F/M	% Caucasian	Education M(SD) years	Total CDR	MMSE Score (range 0-30)	MoCA Score (range 0-30)	s-MoCA score (range 0-16)
All Neurological Diagnoses	653	74.37 (8.89)	381/272	74%	13.95 (4.26)	4.22 (3.36)	22 (6)	16 (7)	6 (4)
AD	340	75.89 (8.24)	220/120	71%	13.39 (4.27)	5.38 (3.27)	20 (6)	14 (6)	5 (3)
MCI	109	72.95 (8.64)	57/52	78%	14.71 (3.96)	1.68 (1.26)	26 (3)	21 (4)	9 (3)
HC	138	70.28 (8.99)	92/46	79%	16.95 (2.74)	0.06 (0.22)	29 (1)	27 (2)	14 (2)

s-MoCA = Short MoCA; CDR = Clinical Dementia Rating Scale (Sum of Boxes)

All significant pairwise comparisons $p < 0.01$.

Age: HC < All Neuro, AD, MCI; AD > MCI;

Sex: HC All Neuro; HC = AD; AD MCI; MCI HC;

Race: HC = All Neuro, AD, MCI

Education: HC > All Neuro, AD, & MCI; MCI > AD

MMSE: HC > All Neuro, MCI, AD; MCI > AD

MoCA: HC > All Neuro, AD, MCI; MCI > AD

Short MoCA: HC > All Neuro, AD, MCI; MCI > AD;

Table 1B
 Diagnostic parameters for the MoCA and Short MoCA in the Full Sample, AD, MCI, PD, and PDD.

		Full Sample vs. HC	AD vs. HC	MCI vs. HC	AD vs. MCI
MoCA	AUC (+/- 95% CI) ^d	0.97 (0.95-0.98)	0.99 (0.99-1.00)	0.95 (0.93-0.98)	0.83 (0.79-0.87)
	Sensitivity/Specificity	0.86/0.96	0.94/1.00	0.94/0.80	0.76/0.78
	Youden Index	0.82	0.94	0.74	0.54
	Cutoff Score	23	22	25	24
	PPV/NPV	0.99/0.59	1.00/0.88	0.78/0.94	0.92/0.51
Short MoCA (s-MoCA)	Classification Accuracy	88%	96%	86%	77%
	AUC (+/- 95% CI)	0.95 (0.94-0.97) [*]	0.99 (0.98-0.99) [*]	0.93 (0.90-0.96) [*]	0.81 (0.76-0.85) ^{*,^}
	Sensitivity/Specificity	0.91/0.85	0.96/0.91	0.87/0.85	0.67/0.79
	Youden Index	0.76	0.87	0.72	0.46
	Cutoff Score	11	10	11	6
MMSE	PPV/NPV	0.97/0.68	0.96/0.91	0.87/0.85	0.91/0.44
	Classification Accuracy	90%	95%	86%	70% ^{*,^}
	AUC (+/- 95% CI)	0.94 (0.92-0.96) [*]	0.98 (0.98-0.99) [*]	0.88 (0.84-0.92) ^{*,#}	0.85 (0.81-0.89)
	Sensitivity/Specificity	0.81/0.96	0.94/0.96	0.75/0.85	0.79/0.79
	Youden Index	0.77	0.90	0.60	0.58
MMSE	Cutoff Score	27	27	28	18
	PPV/NPV	0.99/0.52	0.98/0.88	0.80/0.81	0.92/0.55
	Classification Accuracy	83% [#]	95%	81% [#]	79%

^{*} Significantly lower than the Standard MoCA in permutation testing of AUC using roc.test function in R package pROC (p<0.05).

[#] Significantly lower than the Short MoCA in permutation testing of AUC using roc.test function in R package pROC (p<0.05).

[^] Significantly lower than the MMSE in permutation testing of AUC using roc.test function in R package pROC (p<0.05).

^d Confidence Intervals estimated using DeLong method and n=2000 bootstraps