An Evaluation of the Psychometric Properties of the Montreal Cognitive Assessment Tool when Administered in a Memory Clinic At Groote Schuur Hospital, Cape Town, South Africa.

by

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SUPERVISOR: Professor John JOSKA

CO-SUPERVISOR: Professor Kevin Thomas

10 February 2022

Table of Contents

List of tables

List of figures

Declaration

I, **Yanga Thungana,** solemnly declare that this thesis entitled "*An Evaluation of the Psychometric Properties of the Montreal Cognitive Assessment Tool when Administered in a Memory Clinic at Groote Schuur Hospital, Cape Town, South Africa*." is my original work (except where acknowledgments indicate otherwise). All sources used or quoted in the study have been indicated and acknowledged through complete references. However, neither the whole work nor any part of this work has been, is being, or is to be submitted for another degree at this or any other university.

MASTERS CANDIDATE: **YANGA THUNGANA**

SIGNATURE: Signed by candidate

DATE: ___ **10 February 2022**_____

Acknowledgments

I have received a countless deal of supervision throughout the writing of this dissertation.

Firstly, I would like to thank my supervisor, Professor John Joska, his contribution, and expertise were instrumental from the conceptualization of the research question to the writing of the manuscript. Your ability to allocate time for me in your busy schedule, being patient with my mistakes and your insightful feedback facilitate me to polish my research knowledge and skills.

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Also, I would like to acknowledge my colleagues at the Memory Clinic in Groote Schuur Hospital for their detailed and informative discussion during the case presentations. These discussions helped a lot in formulating my research question and in understanding the subject study.

Additionally, I would like to thank my close group of friends for their unceasing faith in my ability to complete the dissertation timely and their continuous support.

Abstract

Worldwide, the population is aging, and the prevalence of neurocognitive disorders is expected to rise exponentially. Therefore, early detection of dementia is favorable for the patient and may even be of greater significance if disease-modifying treatments are discovered. The Montreal Cognitive Assessment (MoCA) is a reliable and valid cognitive screening tool but is sensitive to several sociodemographic factors, including language, culture, and quality of education. This underscores the need for cognitive screening scales validated in the culturally diverse South African setting.

Aim. The purpose of this study was to investigate the utility of the MoCA as a brief cognitive screening tool in a specialized clinical South African sample.

Methods. A retrospective medical folder review of 162 patients seen at Groote Schuur Hospital Memory Clinic for the first time between January 2014 and August 2021.

Results. The median age of participants was 67 years (IQR 58-73). Most were females (63%, n =102), and had dementia (58%, n = 94); more than half (51%, n = 78) had at least 12 years of formal education. Older age and lower levels of education were associated with lower MoCA scores ($p < 0.001$). At a cut-off of 26/30, the MoCA demonstrated good sensitivity (83%) and specificity (88.9%) for mild cognitive impairment, with lower cut-off scores improving specificity at the expense of sensitivity. Confirmatory factor analysis showed that a six-factor model demonstrated good model fit parameters (Tucker-Lewis index = 0.942, Comparative Fit Index- 0.948, and Root Mean Square Error of Approximation = 0.034). Additionally, the total MoCA scores were significantly correlated with those of the Mini-Mental State Examination, demonstrating good convergent validity ($r = 0.854$, $p < 0.001$).

Conclusion. In a specialized South African clinical setting, the MoCA demonstrated good psychometric properties as a screening tool for evaluating different levels of cognitive impairment. However, to our knowledge, this is the first South African study to assess the factor structure of the MoCA in a clinical setting. More comprehensive and larger studies should evaluate the validity of our findings.

CHAPTER ONE

BACKGROUND

South Africa has a diverse population with eleven official languages and a variety of cultures and religious beliefs. Recent statistics estimate that the number of people in South Africa is around 59.6 million people (Statistics South Africa, 2020). As in other LMICs, the elderly population in South Africa is increasing, with approximately 9.1% of the population being 60 years and older (Statistics South Africa, 2020). In South Africa, there is a wide variation in socioeconomic status (SES), with close to half of the adult population living in poverty (Ataguba et al., 2011; Statistics South Africa, 2019). Moreover, South Africa's education system performs poorly compared to other middle-income countries. Most South African school pupils cannot read, write, and compute at grade-appropriate levels; a large proportion of them are functionally illiterate and innumerate (Mouton et al., 2012; Spaull, 2008).

As a result of this population diversity, wide variations in SES, and relatively low levels of attained education as well as the quality of education, challenges to accurately measuring individual performance on cognitive tests exist. Therefore, any measure used to assess cognitive abilities must take these variables into account. In addition, ageing is associated with increased risk of chronic medical conditions, disability, increased burden of care, which results in increased health-related expenditure (Chatterji et al., 2015; Solanki et al., 2019). South Africa is already experiencing clinical and human resource constraints in delivering health services and the health needs of the increasing ageing population will possibly put further constraints on existing services (Solanki et al., 2019). Optimizing early intervention at the community or primary care level has been identified as key in healthy ageing and reducing healthcare costs (World Health Organization, 2015). Thus, low cost,

easy to use, and reliable screening tools requiring less additional training are urgently needed and can reduce the burden of cognitive disorders of old age.

The Montreal Cognitive Assessment (MoCA) is a brief cognitive screening tool developed to assess mild cognitive impairment (MCI) in Alzheimer's disease (Nasreddine et al., 2005). The original normative sample consisted of highly educated English and French-speaking study participants (Nasreddine et al., 2005). The MoCA has since been translated into more than 60 languages, has been validated in several countries, and has been used for screening for cognitive impairment in many different medical conditions other than Alzheimer's disease (Mahendran et al., 2015).

Although the MOCA has been used in several South African studies as a measure to screen for cognitive impairment associated with a variety of conditions (Beath et al., 2018; Joska et al., 2016; Rademeyer & Joubert, 2016; Robbins et al., 2013), there is a paucity of MoCA validation studies in the South African context. Studies validating the MoCA in languages and cultural settings different from those of the original study have shown that modification of the individual test items of the measure is often necessary (J. bo Hu et al., 2013; Rahman & el Gaafary, 2009; Tsai et al., 2012a). Consistent with these findings, South African clinical experience and the available literature indicate that a few of the MoCA separate items will need to be modified to accommodate the indigenous language and cultural variations (Beath et al., 2018; Robbins et al., 2013). Therefore, the current study sought to evaluate the psychometric properties of the MoCA in a South African Memory Clinic.

Journal of the International Neuropsychological Society

Instructions for authors

The Journal of the International Neuropsychological Society is the official journal of the International Neuropsychological Society, an organization of over 4,500 international members from various disciplines. The Journal of the International Neuropsychological Society welcomes original, creative, high-quality research papers covering all areas of neuropsychology. The focus of articles may be primarily experimental, applied, or clinical. Contributions will broadly reflect the interest of all areas of neuropsychology, including but not limited to: development of cognitive processes, brain-behavior relationships, adult and pediatric neuropsychology, neurobehavioral syndromes (such as aphasia or apraxia), and the interfaces of neuropsychology with related areas such as behavioral neurology, neuropsychiatry, genetics, and cognitive neuroscience. Papers that utilize behavioral, neuroimaging, and electrophysiological measures are appropriate.

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The full text of the manuscript should begin on page 3. For scientific articles, including Regular Research Articles, Brief Communications, Rapid Communications, and Symposia, the format should include a structured Abstract, Introduction, Method, Results, and Discussion. This should be followed by Acknowledgments, References, Tables, Figure Legends, Figures, optional Appendices, and Supplemental Material.

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The Acknowledgements section should include two parts: a Conflicts of Interest disclosure (see above) and a statement to disclose all Funding sources of financial support for the paper. If no Conflicts of Interest exist, you will be required to state as such ("COI: None." or a similar statement). In documenting financial support, please provide details of the sources of financial support for all authors, including grant numbers. For example, "This work was supported by the National Institutes of Health (grant number XXXXXXX)." A comma and space should separate multiple grant numbers. Where research was funded by

more than one agency, the different agencies should be separated by a semicolon with "and" before the final funding agency. Grants held by different authors should be identified using the authors' initials. For example, "This work was supported by the Wellcome Trust (A.B., grant numbers XXXX, YYYY), (C.D., grant number ZZZZ); the Natural Environment Research Council (E.F., grant number FFFF); and the National Institutes of Health (A.B., grant number GGGG), (E.F., grant number HHHH)."

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"...Given the critical role of the prefrontal cortex (PFC) in working memory (Cohen et al., 1997; Goldman-Rakic, 1987; Perlstein et al., 2003a, 2003b)..." with multiple references in alphabetical order. Another example: "...Cohen et al. (1994, 1997), Braver et al. (1997), and Jonides and Smith (1997) demonstrated..."

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Online/Electronic Journal Article with DOI: Dikmen, S., Machamer, J., Fann, J. & Temkin, N. (2010). Rates of symptom reporting following traumatic brain injury. Journal of the International Neuropsychological Society, 16, 401-411. doi:10.1017/S1355617710000196.

Scientific Article: Giovannetti, T., Britnell, P., Brennan, l., Siderowf, A., Grossman, M., Libon, D.J., Seidel, G.A. (2012). Everyday action impairment in Parkinson's disease dementia. Journal of the International Neuropsychological Society, 18, 787-798.

Book: Lezak, M.D., Howieson, D.B., Bigler, E.D., Tranel, D. (2012). Neuropsychological Assessment. New York: Oxford University Press.

Book Chapter: Mahone, E.M. & Slomine, B.S. (2008). Neurodevelopmental disorders. In J.E.Morgan, & J.H. Ricker (Eds.), Textbook of Clinical Neuropsychology (pp. 105-127). New York: Taylor & Francis.

CHAPTER TWO: PUBLICATION READY MANUSCRIPT

The Evaluation of Psychometric Properties of the Montreal Cognitive Assessment Tool When Administered in a Memory Clinic at Groote Schuur Hospital, Cape Town, South Africa.

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Abstract

Objectives

The study sought to evaluate the validity of the Montreal Cognitive Assessment (MoCA) tool in a clinical South African (SA) sample. The objectives were to investigate the suitability of the individual MoCA items in the SA context, to explore the instrument's utility in screening for cognitive impairment, and to use confirmatory factor analysis to investigate the factor structure of the MoCA in the current sample.

Methods

A retrospective medical folder review of 162 patients seen for the first time at Groote Schuur Hospital Memory Clinic between January 2014 and August 2021.

Results

The median age of participants was 67 years (IQR 58-73). Most were females (63%, n =102) and had dementia (58%, n = 94); more than half (51%, n = 78) had attained least 12 years of formal education. Older age and lower levels of education were associated with lower MoCA scores ($p < 0.001$). The MoCA demonstrated good sensitivity (83%) and specificity (88.9%) for mild cognitive impairment at the cut-off score of 26/30. Confirmatory factor analysis showed that a six-factor model demonstrated good model fit parameters (Tucker-Lewis index = 0.942, Comparative Fit Index- 0.948, and Root Mean Square Error of Approximation = 0.034). Additionally, the total MoCA scores were significantly correlated total Mini-Mental State Examination score, demonstrating good convergent validity ($r = 0.854$, $p < 0.001$).

Conclusion

In a specialized South African clinical setting, the MoCA demonstrated good psychometric properties as a screening tool for evaluating different levels of cognitive impairment. Additionally, this is the first South African study to assess the factor structure of the MoCA in a clinical setting. More comprehensive and larger studies should evaluate the validity of our findings.

Introduction

As the global population of elderly individuals grows, aging remains the most consistent risk factor for developing dementia (Lane et al., 2018; Prince et al., 2015). Dementia is a significant public health concern (Prince et al., 2013; Sapkota & Subedi, 2019); It is among the leading causes of death globally and a significant cause of disability among the aged worldwide (Sapkota & Subedi, 2019). Therefore, detecting the early phases of cognitive disorders is beneficial to both the patients and their families or caregivers (Rasmussen & Langerman, 2019).

The Montreal Cognitive Assessment (MoCA) is a brief cognitive screening tool initially developed to assess mild cognitive impairment (MCI) in Alzheimer's disease (Nasreddine et al., 2005). The MoCA has shown good psychometric properties as a screening tool for MCI and dementia, mainly in high-income countries (Carson et al., 2018; Cumming et al., 2013; Nasreddine et al., 2005). However, several sociodemographic factors such as age, education, marital status, and sex affect MoCA performance. For instance, higher age and lower levels of education are associated with lower scores on the MoCA (Beath et al., 2018; Freitas, Simões, Marôco, et al., 2012; Rossetti et al., 2011). Participants' sex might also influence the MoCA performance, with some studies indicating that men tend to achieve scores lower than women (Borland et al., 2017; Konstantopoulos et al., 2016; Larouche et al., 2016). Moreover, the individual MoCA items are susceptible to cultural and linguistic artifacts, thus affecting the validity of the instrument in settings outside of which it was developed (Y. Dong et al., 2010; J. bo Hu et al., 2013; Lee et al., 2008; Yu et al., 2012).

The MoCA's developers postulated that it assessed six cognitive domains (language, attention/concentration, memory, orientation, visuospatial and executive function) which together measure the construct of general cognitive functioning (Nasreddine et al., 2005). However, the MoCA's factor structure remains a matter of debate; there is no clear consensus on whether it is unidimensional or multidimensional. Furthermore, although some studies (Freitas et al., 2015; Luo et al., 2019a) have provided statistical evidence supporting the unidimensionality of the MoCA, in many instances, the unidimensionality of the MoCA is proposed based on clinical and neuropsychological knowledge but is not empirically tested (Delgado et al., 2019; Nasreddine et al., 2005).

Although a reasonably extensive literature suggests the MoCA is a multidimensional measure with a general factor (Coen et al., 2016; Freitas et al., 2015; Freitas, Simões, Marôco, et al., 2012; Nasreddine et al., 2005; Vogel et al., 2015), there is no consensus on the exact number of latent factors (Freitas et al., 2015; Vogel et al., 2015). Nonetheless, this literature supports the idea that the MoCA, in addition to measuring the total cognitive ability, generates sub-scores that reflect performance within specific cognitive domains and thus allows examination of separate index scores that might refine the test-taker's cognitive profile (Freitas, Simões, Marôco, et al., 2012).

Compared with other global cognitive assessment tools, the MoCA demonstrates excellent convergent validity (Freitas, Simões, Alves, et al., 2012; Lam et al., 2013; Tsai et al., 2012b). Additionally, scores on individual MoCA domains are highly correlated with scores on standard neuropsychological measures, suggesting that the MoCA domains measure similar constructs as those derived from the more comprehensive neuropsychological batteries (Lam et al., 2013; Vogel et al., 2015). However, there is no consensus regarding the optimal cutoff score of the MoCA for detecting MCI, with scores

ranging between 18 and 25 across different studies (Ciesielska et al., 2016; Y. H. Dong et al., 2012; Nasreddine et al., 2005; Tan et al., 2014). In South Africa, cut-off scores lower than the recommended 26 for detecting MCI might be more realistic (Beath et al., 2018; Robbins et al., 2013).

Several studies have eluded the need to modify the individual MoCA items in settings outside the original study sample (J. bo Hu et al., 2013; Rahman & el Gaafary, 2009; Tsai et al., 2012b). As a result, it should be expected that some MoCA test items might need to be adapted to accommodate the South African linguistic and cultural variations. For instance, in the South African context, some MoCA items may be unsuitable (serial 7's and abstraction item – rule and watch), too unfamiliar (three-dimensional cube copy), and problematic (e.g., phonemic tasks and sentence repetition in other local SA languages) (Beath et al., 2018; Ganasen et al., 2008; Robbins et al., 2013).

Since several factors in South Africa (SA) such as low level of education, poor quality of education, population diversity, and variation in SES can affect the MoCA performance. The current study sought to examine whether the MoCA is evaluating the same construct of cognition despite the differences in the SA context compared to those of the original setting of the MoCA. Therefore, we used confirmatory factor analysis to assess the instrument's factor structure in the current sample. Moreover, we evaluated the performance of individual MoCA items to evaluate the appropriateness and need for modification of the MoCA items in the South African clinical context. Lastly, we scrutinized the ability of the MoCA to discriminate participants with MCI and dementia from those with no cognitive impairment.

Methods and Materials

Study design

We conducted a retrospective chart review using a cross-sectional analytic design. In addition, medical folders of patients who attended Groote Schuur Hospital Memory Clinic (Cape Town, South Africa) between January 2014 and August 2021 were reviewed.

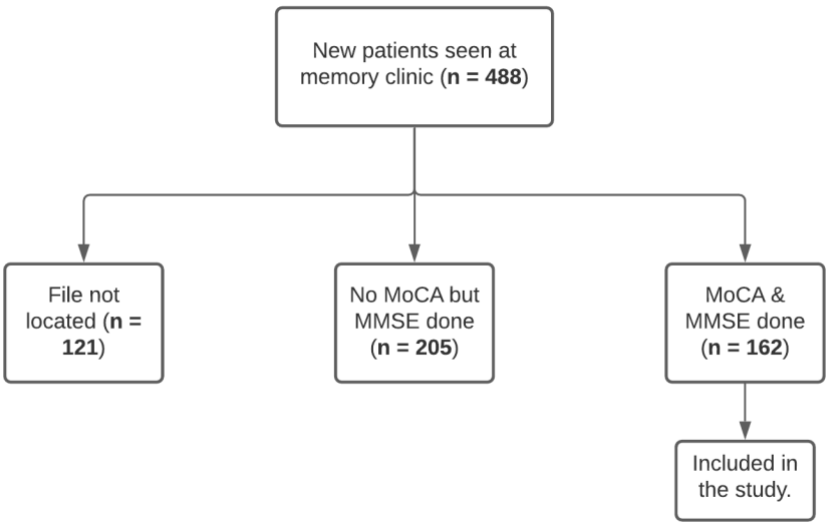
Participants

The GSH memory clinic is run by a multidisciplinary team (MDT) consisting of geriatric physicians, neuropsychiatrists, and neuropsychologists. It is a specialist clinic that receives referrals from neighboring hospitals and clinics. The study included all the patients who attended the Clinic as new patients between January 2014 and August 2021 and who (1) were assessed by members of the multidisciplinary team, including administration of neuropsychological tests and informant-reported psychiatric scales, and (2) had their case discussed at the team's weekly clinical case conference.

The typical GSH Memory Clinic patient is an older adult with several medical or psychiatric comorbidities, although younger patients are occasionally seen. Therefore, there was no age restriction for the study, and neither medical nor psychiatric comorbidities were used as grounds for exclusion from the study.

Figure 1

Selection of Study Participants



Procedure

The initial evaluation of a patient attending the Memory Clinic for the first time includes clinical assessment by a geriatric physician/registrar or neuropsychiatrist/registrar and a cognitive test battery administered by a neuropsychologist. In addition, the patient informant or caregiver completes psychiatry scales. The case is then presented at a case conference later the same day. Based on all available evidence, the team decides whether there is no cognitive impairment, mild cognitive impairment, or major neurocognitive disorder with specified severity. The team also reviews or requests laboratory investigations and neuroimaging to delineate the possible causes of cognitive dysfunction in each patient.

Measurements

Neuropsychological Tests

Mini-Mental State Examination (MMSE; (Folstein et al., 1975)), a brief bedside cognitive screening test, was administered to all the participants. The MMSE assesses orientation, attention, verbal coding and delayed recall, language (naming, writing, and comprehension), and visual-spatial skills. The possible score range is 0-30.

Subtests from the Repeatable Battery for the Assessment of Neuropsychological Status (RBANS; (Randolph et al., 1998)) were used to assess cognitive domains, including immediate recall (list learning and story memory), delayed recall (list recall, list recognition, story recall, and complex figure recall), and visuospatial abilities (complex figure copy).

The Boston Naming Test- South African Short Form (BNT-SA-SF) was used to test confrontational naming (Thomas et al., 2019). Patients were shown line drawings of 15 objects, ranging from those depicting high-frequency words images to those depicting less frequently encountered words.

Other cognitive tests included assessing working memory (forward and backward digit span), visuospatial abilities (clock drawing tests - CLOCK 1 and CLOCK 2), and executive functions – fine motor skills and sequencing (Luria I: fist-edge and Luria II: palm-fist-edge), trail making test (timed trail A 1-8, and 1-25), pattern recognition test, and the Mental Alternation Test.

Montreal Cognitive Assessment

The neuropsychologist also administers the MOCA to all the patients. The MoCA was administered in English to all participants and no modification of MoCA items was done as this was a retrospective study. The MOCA assesses spatial and temporal orientation,

attention, concentration, working memory, visuospatial abilities, language, verbal episodic memory, and executive functioning. The maximum MoCA score is 30, with higher scores indicating better cognitive functioning. The total score is adjusted for education by adding one point for those with less than 12 years of formal education.

The MoCA was only routinely administered as a formal part of the neuropsychological test battery from January 2019. However, it was occasionally administered separately from the neuropsychological battery before that date.

Caregiver Psychiatry Scales

All of the following instruments were completed by a caregiver or other informant. The Bristol Activities of Daily Living Scale (BADLS; (Bucks et al., 1996)) evaluates the ability of an individual with cognitive impairment to successfully carry out basic and instrumental activities of daily living. The Memory Clinic team uses a modified 17-item version of this instrument. The Cornell Scale for Depression in Dementia is a screening tool that evaluates the extent to which the patient is perceived to experience different symptoms of depression (Alexopoulos et al., 1988).

The Neuropsychiatric Inventory and Caregiver Distress Scale (NPI-D) is designed to assess neuropsychiatric disturbances in patients with dementia and evaluate the extent to which these cause distress in the caregiver (Kaufer et al., 1998). The Deterioration in Cognitive Observee (DECO) is a 19-item screening test used to evaluate the extent to which functioning has declined over the past year in dementia patients with cognitive symptoms(Ritchie & Fuhrer, 1996). The Apathy Evaluation Scale (Informant) is an 18-item Likert-type scale used to evaluate the presence and severity of apathy by assessing the three dimensions of apathy, namely cognitive, behavioural, and affective (Marin et al., 1991).

Data analysis

All statistical analyses were conducted using STATA 16 SE. Microsoft Excel was utilized for the graphical representation of the study data. First, a complete set of descriptive statistics characterized the dataset's continuous variables (means and standard deviations for normally distributed data, modes and interquartile ranges for non-normally distributed data) and categorical variables (frequencies and proportions). Second, we evaluated the sensitivity and specificity of the MoCA in accurately screening for MCI and dementia by comparing its performance against the gold standard of the clinical case conference diagnosis. Following the convention established by Nasreddine et al. (2005), we set the MoCA threshold for cognitive impairment at a score of < 26. For comparative purposes, we set the MMSE threshold at the same level.

Third, we evaluated the performance of individual MoCA items by calculating the percentage of correct responses (across the entire sample and within each of the MCI and dementia groups separately) for each dichotomously scored item. Finally, to analyze the discriminating power of individual items and cognitive domains, we estimated (using Pearson's correlation coefficient) the magnitude of association between (a) each item score and the MoCA total score, (b) each item score, and the score on each of the six cognitive domains, and (c) scores on each of the six cognitive domains and MoCA total score. Significant correlation coefficients are an indicator of factorial validity.

Also, bivariate analysis were performed for categorical variables using either the Pearson's chi-square test, unpaired t-test, or Wilcoxon rank-sum test and the significance level set at $P < 0.05$. Several MoCA cutoff scores have been suggested for detecting MCI (Carson et al., 2018; Goldstein et al., 2014; Luis et al., 2009; Milani et al., 2018). Therefore, we calculated MoCA sensitivity and specificity using clinical diagnosis as the standard using

various MoCA cutoff scores. Finally, we estimated the internal consistency reliability of the MoCA in the current sample using Cronbach's alpha coefficient, and a score equal to or higher than 0.7 suggests good reliability (Hair Jr et al., 2010).

Finally, we evaluated the construct validity of the MoCA using confirmatory factor analysis (CFA; (K Muthén & O Muthén, 2017)). In evaluating the internal consistency of the MoCA, the Cronbach's alpha (α) for this sample was 0.901, confirming the excellent reliability of the MoCA. In addition, further analysis indicated that the exclusion of each MoCA item did not improve the reliability coefficient value of the scale. Therefore, in this analysis, items with a correct response frequency $\geq$ 95% in the overall sample (k = 3; clock contour, lion, and place) were excluded to avoid estimation problems arising from ceiling effects.

To assess the suitability of the sample to proceed with CFA, we performed the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's test. The respective values were KMO = 0.859 and $p < .001$, indicating that we could proceed as planned. Based on previous research and theories regarding the MoCA's factor structure, we tested four models: a one-factor model (Duro et al., 2010), a two-factor model (Duro et al., 2010), a six-factor model (Freitas, Simões, Marôco, et al., 2012), and a one-factor second-order model (Freitas, Simões, Marôco, et al., 2012). The one-factor second-order model considers that all those six factors contribute to a common underlying second-order factor that would indicate a unidimensional tendency of the scale. We used these statistics to assess model fitness: the Root Mean Square Error of Approximation (RMSEA), where values closer to 0.06 suggest a good model fit; the Comparative Fit Index (CFI) and Tucker-Lewis Index (TLI), where values closer to 1.0 suggest a good model fit. We also used the chi-square (χ^2) test, where lower values indicate better model adjustment. Ideally, a non-

significant χ^2 is preferred, but its dependency on the sample size limits the test. Therefore, a combination of CFI and TLI >0.9 with a low RMSEA (closer to 0.06) is recommended in assessing the goodness of model fit (Byrne, 2010; L. T. Hu & Bentler, 1999).

Ethics Approval

Approval to conduct the research was obtained from the Chief Operational Officer at Groote Schuur Hospital and the University of Cape Town's Faculty of Health Sciences Human Research Ethics Committee. All research protocols were conducted following guidelines contained in the Declaration of Helsinki (Ebihara, 2000).

Results

The median age of the 162 participants who constituted the total study sample was 67 years (IQR 58 – 73; **Table 1**). Most participants were females (62.96%, n = 102), white (54.6%, n = 84), and received a state grant (57.7%, n = 86). More than half of the participants had at least 12 years of formal education (51%, n = 78). On assessment, most patients had an active psychiatric disorder (59.3%, n = 96) and were diagnosed with dementia (58%, n = 94). The two most common causes of cognitive decline, whether MCI or dementia, were vascular cognitive impairment (24.7%, n = 40) and Alzheimer's disease (23.5%, n = 38).

Analyses detected a significant negative association between MoCA total score and age, with increasing age associated with lower scores (r_s -0.2, p = .01, N = 162). Analyses also detected a statistically significant positive correlation between the MoCA total scores and the participant's level of education (r_s 0.3, p <.001, N = 153). For instance, those with less than a grade 12 education (M= 21.9, SD= 5.4) scored less than those than those with

at least a grade 12 qualification (M= 25.2, SD= 4.8), t(137) = -3.9, p < .001. The difference was despite adjusting for the effect of education by adding a point to each participant with less than 12 years of formal education. Analyses detected no significant association between MoCA total scores and participant sex.

Sensitivity and Specificity of the Montreal Cognitive Assessment

As expected, participants deemed by the Memory Clinic team to have no detectable cognitive impairment achieved better MoCA scores (M±SD = 27.4±2) than those with MCI (22.8±2.8), who in turn achieved better scores than those with dementia (14.5±5.1; see **Fig 2**). These between-group differences were statistically significant [F(2,159) = 90.11, p < .001].

Of further interest in **Figure 2** is that the mean scores of the participants with MCI were within the normal range on the MMSE (i.e., ≥ 26) but in the clinical range for the MoCA (i.e., < 26). A scatterplot of the MMSE and MoCA scores together (**Fig 3**) shows that most participants with dementia (83.9%) scored in the abnormal range on both instruments. In contrast, the majority (69.8%) of participants with MCI scored in the abnormal range on the MoCA but within the normal range on the MMSE.

At the predetermined cut-off score of 26/30, the MoCA demonstrated good sensitivity in identifying MCI (83%) and excellent sensitivity in recognizing dementia (99%). In contrast, the sensitivity of the MMSE was 19% and 84%, respectively. The smaller number of participants assessed not to have cognitive impairment limited the calculation of specificity. Our study delineated specificity as participants demonstrated no cognitive impairment and scored≥26 on the MoCA or MMSE. The MMSE demonstrated better specificity than the MoCA (100% vs. 88.9%).

Because several different MoCA cutoff scores have been suggested as being optimal for the diagnosis of MCI (see, e.g., (Beath et al., 2018; Luis et al., 2009; Milani et al., 2018), we calculated the sensitivity and specificity of the instrument in screening for that diagnosis at those various cutoff scores. **Table 2** shows that the sensitivity of the MoCA decreases as the cutoff score decreases, whereas the opposite pattern is true for specificity. The MoCA also demonstrated high positive predictive values in detecting MCI, suggesting that a patient with a MoCA score above the clinical threshold is more likely to have true cognitive impairment. However, the relatively low negative predictive values indicate that the MoCA is not an adequate measure to exclude the presence of MCI.

Analysis of the MoCA Individual Items and Cognitive Domains

Table 3 shows the distribution of response frequencies for each of the 32 dichotomously scored MoCA items for the overall sample and the MCI and dementia groups separately. Four items (clock contour, lion, place, and city) had a consistently high hit rate (> 90%), suggesting a low index of difficulty. Five additional items within the MCI group (subtraction 1, camel, day, month, and year) also had a high hit rate. In contrast, the memory items (recall – face, velvet, church, daisy, and red) had markedly low hit rates (< 30%) in the overall sample. They were the lowest scoring items in both the MCI and dementia groups.

As **Table 4** shows, the analyses detected significant positive correlations between the percentage of correct responses and MoCA total score (p <.001). Of note is that the items identified earlier as having the highest hit rates (clock contour, lion, place, and city) had weaker associations (r =.228, .323, .300, and .246, respectively), suggesting they contribute the least individual information obtained with the MoCA. Table 4 also shows that all the MoCA items (except the four with high hit rates) had the highest correlation

with their respective cognitive domain than any other domain. However, Phonemic Fluency contributed almost equally to two domains (language and executive function), as conceptualized in the original sample (Nasreddine et al., 2005).

As **table 5** shows, the correlations between each cognitive domain score and MoCA total score were all strongly positive and statistically significant (all *ps* < .001), providing evidence for construct-related validity of the MoCA in this sample. Additionally, the fact that correlations between domain scores and MoCA total scores were stronger than those between the domains suggests the discriminative power of the domains. Likewise, the total MoCA score was highly correlated with the MMSE score (r = 0.854, p < .001, N = 148). Moreover, there was a significant correlation between the cognitive domains of the MoCA and MMSE, suggesting a good concurrent validity of the scale (*ps* < .001).

Confirmatory Factor Analysis

Analyses indicated that the one-factor second-order model failed to converge during CFA and would not improve with removing items with low covariances. Therefore, we could not calculate the model fit parameters for this model. **Table 6** presents the results for the other three models.

As the Table shows, the single-factor and two-factor models showed poor fit characteristics (CFI and TLI < .90, RMSEA > 0.06). In contrast, the six-factor model postulated by the MoCA's developers demonstrated a much better fit (CFI and TLI > .90, SRMR < 0.08, RMSEA < 0.06). The six-factor model comprises short-term memory (delayed recall of 5 items), executive function (trail making test, abstraction 1& 2, phonemic fluency), language (confrontation naming, sentence repetition, phonemic fluency), visuospatial skills (cube copy and clock drawing), orientation (6 items for spatial and time

orientation), and attention, concentration, and working memory (sustained attention, digit forwards, and digits backward).

Discussion and Conclusion

This study investigated the Montreal Cognitive Assessment (MoCA) psychometric properties as a cognitive screening tool in a specialized memory clinic population. We found a significant positive correlation between education and MoCA total score (even after adjusting the education variable by adding a point for those under 12 years of education, there was on average a 4-point score difference between those who had completed high school and those with less than 12 years of formal education) and a significant negative correlation between age and MoCA total score. However, our analyses detected no significant association between MoCA scores and participants' sex. In addition, the MoCA demonstrated good-to-excellent sensitivity and specificity in screening for MCI and dementia. Lastly, confirmatory factor analysis suggested that a six-factor model had better fit parameters than the other models tested.

Although several previous studies have described the significant relationship between MoCA performance and the level of education, there is no consensus solution to adjust for the effects of increasing educational exposure on MoCA scores (Beath et al., 2018; Bruijnen et al., 2020; Chertkow et al., 2011; Nasreddine et al., 2005). A conventional approach adds one point to the total scores of those with less than 12-years of education. However, several researchers argue that this is arbitrary and insufficient to nullify the observed education effects (Milani et al., 2018). That certainly appears to be the case in the current sample. Therefore, another suggestion is to add points according to the level of education, not the duration of education; this would include adding 2 points for those

with only primary education and one point for those with only secondary education (Bruijnen et al., 2019; Delgado et al., 2019).

Our findings of a significant negative association between MoCA performance and age; and no significant association between MoCA performance and sex are consistent with the general tenor of the literature (Apolinario et al., 2018; Bruijnen et al., 2020; Kopecek et al., 2017; Malek-Ahmadi et al., 2015; Oren et al., 2014; Santangelo et al., 2015).

In the current sample, the MoCA total score could discriminate patients with MCI from those with dementia, indicating good discriminant validity. Unfortunately, our relatively small sample size means we could not test its ability to discriminate between dementia of different causes. However, previous studies suggest that MoCA scores vary significantly between dementia subtypes (e.g., AD, vascular dementia, and frontotemporal dementia), so the MoCA can aid in detecting and classifying these disorders (Coleman et al., 2016; Duro et al., 2010).

Consistent with findings from previous studies, in the current sample, the MoCA showed better sensitivity in detecting MCI than the MMSE (Y. H. Dong et al., 2012; Duro et al., 2010; Larner, 2012). Although several recent studies suggest that the MoCA's conventional cutoff score (26/ 30) is adequately sensitive but less specific in detecting MCI, leading to a high false-positive rate (Goldstein et al., 2014; Milani et al., 2018; Rossetti et al., 2017; Sink et al., 2015). Consequently, several different cutoff scores have been suggested, but there remains no consensus regarding which delivers the optimal balance of sensitivity and specificity. This lack of consensus may be attributed to the varied performance of the MoCA in different study settings (Y. H. Dong et al., 2012; Goldstein et al., 2014; Julayanont et al., 2013; Luis et al., 2009). For instance, in specialized memory clinic settings, lower scores may be more sensitive considering that most patients primarily

have cognitive complaints compared to the admixture of patients in general geriatric clinics. In our sample, the cutoff of 26 performed better. In contrast, a recent South African study using a healthy non-clinical sample found that sensitivity and specificity were better at a cut-off of 24 than at 26 (Beath et al., 2018).

The MoCA's developers theorized that the instrument measured performance across six distinct cognitive domains. Therefore, the distinct scores of cognitive performance could be summed to a single construct of general cognition (Nasreddine et al., 2005). However, there is an ongoing debate about whether the MoCA total score reflects one general factor or more factors. Although there is some empirical evidence supporting the postulation that the MoCA is fundamentally a unidimensional instrument (Freitas et al., 2015; Luo et al., 2019a); there is also evidence indicating that it is multidimensional with an underlying general factor (Freitas et al., 2015; Freitas, Simões, Marôco, et al., 2012; Luo et al., 2019b). In contrast, other studies have found that the MoCA is multidimensional without a general factor (Coen et al., 2016; Duro et al., 2010). Our findings are consistent with the latter set of studies. However, it is essential to note that most studies support the multidimensionality of MoCA items but with an underlying general factor (Delgado et al., 2019; Freitas, Simões, Marôco, et al., 2012; Luo et al., 2019b; Sala et al., 2020). These cross-study differences in psychometric findings might be attributed to diversity in study settings (e.g., clinical samples vs. community samples).

With few exceptions, analyses of individual MoCA items suggested the scale is psychometrically adequate for the purpose. Furthermore, and consistent with previous studies, the instrument's internal consistency was high (Duro et al., 2010; Freitas, Simões, Marôco, et al., 2012; Sala et al., 2020). Although previous studies found that items with a high hit rate did not compromise the model fit significantly (Freitas, Simões, Marôco, et al.,

2012; Sala et al., 2020); in our study, the inclusion of these items in the analyses led to a notable drop in the model fit. Moreover, some literature suggests that primarily the same MoCA items (viz., clock contour, lion, city, and place) have high hit rates and low correlations with the total score, possibly challenging their continued inclusion in the scale (Freitas, Simões, Marôco, et al., 2012; Sala et al., 2020).

The MoCA items (daisy, letter fluency, and cube copy) might need to be modified to improve the validity of the MoCA in the South African population. For instance, while the memory recall item consistently scored low in most participants, the recall of the word daisy was notable remembered less than the other four words. One possible explanation is that the word is too unfamiliar to people not fluent in English. Also, most participants could not copy the cube correctly or correctly complete the phenomic fluency task. Therefore, a three-dimensional drawing might be too complex for those with low levels of education, and substituting the cube with a simpler drawing might be a solution (Gõmez et al., 2013; Robbins et al., 2013). Additionally, phenomic fluency could be substituted with semantic fluency as phenomic fluency might be too difficult for the illiterate (Buriel et al., 2004; García-Laredo et al., 2015)and unfamiliar with participants speaking indigenous South African languages (Robbins et al., 2013).

We note the following limitations of our study. First, the relatively small sample size and exclusive inclusion of participants attending a specialized memory clinic may restrict the generalizability of the findings. In addition, the high proportion of white participants and having more than half of participants with at least 12 years of formal education in our study is not reflective of the South African reality and further limits the study's generalizability. Second, tests within the neuropsychological battery administered in our memory clinic are not all wholly validated and standardized for use in the South African

clinical context, so relying on the clinician's expertise for interpretation. However, the fact that all patients are discussed, including all aspects of neuropsychological testing in a multidisciplinary team in making a final clinical diagnosis, allows for consistency in patient assessment.

Conclusion

Using data from a retrospective medical folder review of 162 patients seen at a specialized memory clinic in Cape Town, South Africa, we conducted a comprehensive psychometric analysis of the Montreal Cognitive Assessment. The instrument demonstrated good psychometric properties as a screening tool for evaluating MCI ad dementia. Not only did the MoCA give information regarding global cognition, but it also, to a limited degree, discriminated between dysfunctions of different cognitive domains. Thus, our findings corroborate the MoCA's factorial, convergent, and discriminant validity. Although our data suggest the MoCA is an effective tool in a LMIC clinical context, there is still a need to replicate our findings in larger studies that use detailed neuropsychological testing, especially those that focus on MCI patients. There is also a need for more comprehensive and larger local studies to help establish contextually appropriate cut-off scores for the MoCA.

Acknowledgments and author contribution

There are no conflicts of interest to disclose for all the individuals who authored this paper. **YT** – Conceptualization, Methodology, Visualization, Data Analysis, and Writing – original draft, review, and editing. **JAJ** – Conceptualization, Methodology, and Writing – reviewing and editing. **KT** – Methodology and Writing – reviewing and editing.

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6.0 TABLES AND FIGURES

Table 1

Sociodemographic Details (N =162)

Parameter	Number (Percentage)	MCI (n = 59)	Dementia (n= 94)
Median age (IQR)	67 years (58 - 73)	64 years (58 – 72)	69 years (59 – 74)
Sex			
Male	60 (37%)	24 (40%)	35 (58.3%)
Female	102 (63%)	35 (34.3%)	59 (57.8%)
Completed high school			
Yes	78 (51%)	35 (63.4%)	35 (39.3%)
No	75 (49%)	20 (36.6.7%)	54 (60.7%)
Current psychiatric Disorder			
Yes	96 (59.3%)	42 (43.7%)	48 (50%)
No	66 (40.7%)	17 (25.8%)	46 (69.7%)
Race			
White	84 (54.6%)	-	-
Colored	48 (31.2%)	-	-
black	11 (7.1%)	-	-
Unknown	11 (7.1%)	-	-

Table 2

Montreal Cognitive Assessment Properties in Screening for Mild Cognitive Impairment

Cut-off score	Sensitivity	Specificity	PPV	NPV
26/30	83%	88.9%	98%	44.4%
25/30	71.2%	88.9%	97.7%	32%
24/30	59.3%	100%	100%	27.3
23/30	42.4%	100%	100%	20.9%
22/30	28.9%	100%	100%	14.8%

Table 3

Distribution of Responses for the Individual Montreal Cognitive Assessment Items

MOCA item	Incorrect %	Correct %	MCI - correct %	Dementia - correct %
MOCA Trail	45.9	54.1	72.9	40.1
MOCA cube copy	61.5	38.5	57.6	23.1
Clock contour	4.4	**95.6**	**98.3**	**93.5**
Clock numbers	30.8	69.2	86.4	56
Clock hands	64.4	35.6	52.5	22.8
Lion	4.9	**95.1**	**100**	**91.5**
Rhinoceros	24.7	75.3	89.8	63.8
Camel	12.4	87.6	**98.3**	79.8
Digits forward	24.2	75.8	87.9	66
Digits backward	25	75	86.2	66
Letter A	35.4	64.6	86.2	47.9
Subtraction 1	20.4	79.6	**96.6**	67
Subtraction 2	53.1	46.9	66.1	30.9
Subtraction 3	53.1	46.9	67.8	30.9
Subtraction 4	51.9	48.1	66.1	33
Subtraction 5	61.1	38.8	59.3	23.4
Sentence one	33.5	66.5	89.8	48.4
Sentence two	59.9	40.1	69.5	18.1
Letter fluency	68.5	31.5	44.1	20.2
Abstraction 1	46.3	53.8	74.1	37.6
Abstraction 2	63.1	36.9	60.3	18.3
Date	39.5	60.5	86.4	40.4
Month	21.6	78.4	**93.2**	67
Year	25.3	74.7	**93.2**	60.6
Day	17.3	82.7	**96.6**	72.3
Place	4.9	**95.1**	**100**	**91.5**
City	5.6	**94.4**	**98.3**	**91.5**
Face	79.6	20.4	32.2	6.4
Velvet	76.5	23.5	37.3	8.5
Church	72.2	27.8	42.4	13.8
Daisy	82.7	17.3	23.7	7.5

Red	73.5	26.5	42.4	11.7

Note. MCI, mild cognitive impairment

Table 4

Correlation Coefficients of Montreal Cognitive Assessment Items with Total Score and Cognitive Domains.

	Total score	ACWM	Orient	memory	Language	VSS	Exec Fx
MOCA Trail	.455**	.330**	.273**	.187*	.245*	.430**	**.624****
MOCA cube copy	.499**	.391**	.310**	.151	.350**	**.721****	.406**
Contour	.228*	.221*	.164*	.099	.132	.181*	.078
Clock numbers	..575**	.500**	.401**	.279**	.309**	**.694****	.379**
Clock hands	.477**	.337**	.353**	.279**	.237*	**.749****	.301**
Lion	.323**	.205*	.247*	.164*	.236*	.211*	.140
Rhinoceros	.483**	.268**	.276**	.288**	**.608****	.225*	.364**
Camel	.417**	.176*	.294**	.247*	**.554****	.249*	.251*
Digits forward	.411**	**.584****	.278*	.193*	.322**	.227*	.300**
Digits backward	.429**	**.650****	.201*	.151	.197*	.328**	.242*
Letter A	.524**	**.623****	.361**	.285**	.413**	.317**	.389**
Subtraction 1	.567**	**.662****	.444**	.269**	.281**	.457**	.333**
Subtraction 2	.478**	**.645****	.262**	.249*	.225*	.452**	.246*
Subtraction 3	.530**	**.686****	.306**	.157*	.292**	.500**	.397**
Subtraction 4	.570**	**.741****	.360**	.270**	.266**	.477**	.384**
Subtraction 5	.509**	**.627****	.294**	.192*	.301**	.446**	.377**
Sentence one	.541**	.393**	.463**	.227*	**.697****	.317**	.430**
Sentence two	.540**	.292**	.357**	.251*	**.780****	.302**	.486**
Letter fluency	.505**	.361**	.289**	.217*	**.681****	.289**	**.664****
Abstraction 1	.525**	.377**	.358**	.168*	.486**	.347**	**.726****
Abstraction 2	.492**	.312**	.339**	.170*	.436**	.317**	**.718****
Date	.586**	.356**	**.778****	.362**	.347**	.316**	.360**
Month	.624**	.423**	**.804****	.322**	.379**	.460**	.343**
Year	.610**	.384**	**.765****	.340**	.476**	.374**	.386**
Day	.553**	.307**	**.779****	.289**	.395**	.370**	.333**
Place	.300**	.173*	.287**	.129	.197*	.181*	.171*
City	.246*	.164*	.327**	.141	.113	.210*	.183*
Face	.453**	.269**	.282**	**.727****	.276**	.296*	.208*
Velvet	.519**	.247*	.315**	**.775****	.311**	.271**	.188*

Church	.518**	.241*	.352**	**.810****	.283**	.259**	.206*
Daisy	.460**	.259**	.318**	**.741****	.228*	.196*	.207*
Red	.522**	.237*	.347**	**.763****	.278**	.344**	.226**

Note. ***ACWM*** - attention, concentration and working memory; ***Orient*** - orientation; ***VSS*** - visuospatial skills; ***Exec fx*** - executive function. * p< 0.05 ** p < 0.001

Table 5

Correlation Coefficients between Cognitive Domains and Total Score

	Total score	Memory	Exec Fx	VSS	Language	ACWM	Orientation
Total score	-						
Memory	.649	-					
Exec Fx	.729	.271	-				
VSS	.715	0.335	.508	-			
Language	.744	.362	.679	.412	-		
ACWM	.761	.330	.506	.569	.450	-	
Orientation	.760	.424	..459	.492	.501	.478	-

Note. All correlation coefficients were significant at the level of p<0.001. **ACWM** = attention, concentration and working memory; Memory = short-term memory; **VSS** = visuospatial skills; **Exec fx** = executive functions

Table 6

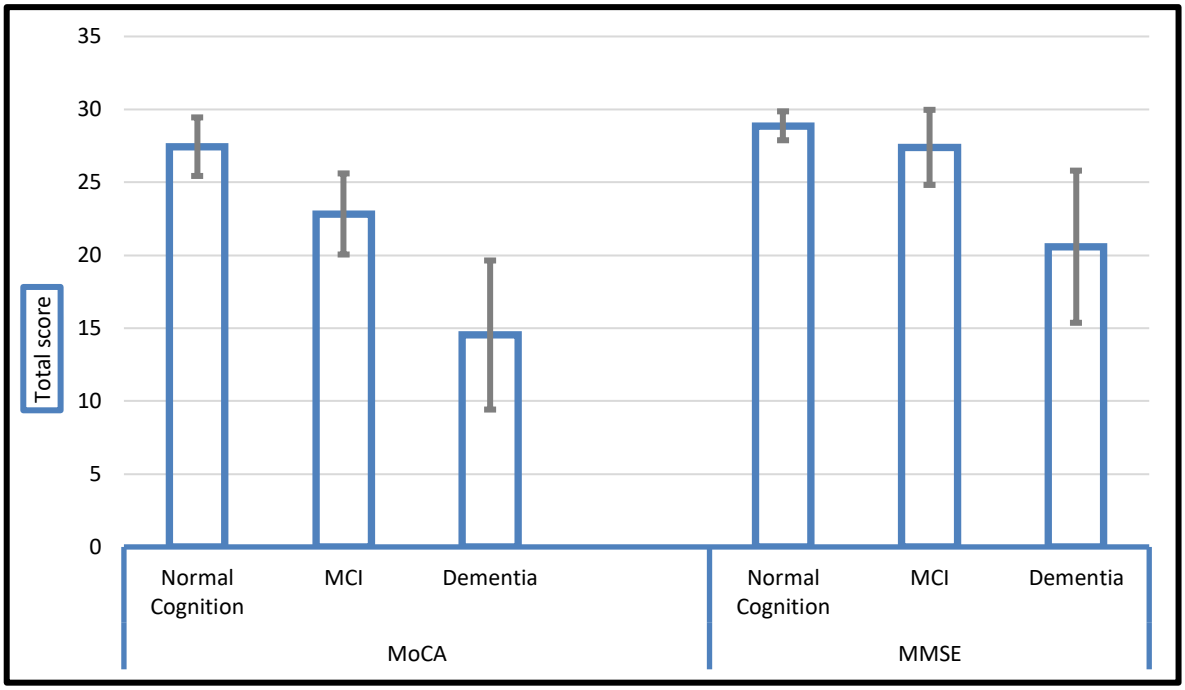
Goodness-of-fit Statistics for Confirmatory Factor Analysis

Model	χ^2	df	p-value	χ/df	SRMR	CFI	TLI	RMSEA
1-factor	129.184	27	<0.001	5	0.107	0.815	0.753	0.157
2-factor	646.431	349	<0.001	2	0.090	0.756	0.736	0.075
6-factor	426.440	361	0.010	1	0.064	0.948	0.942	0.034

Note. χ - chi square; **df** - Degrees of freedom of the model; **SRMR** - Standardised root mean squared residual; **CFI** - Comparative fit index; **TLI** - Tucker-Lewis index; **RMSEA** - Root mean squared error of approximation

Figure 2

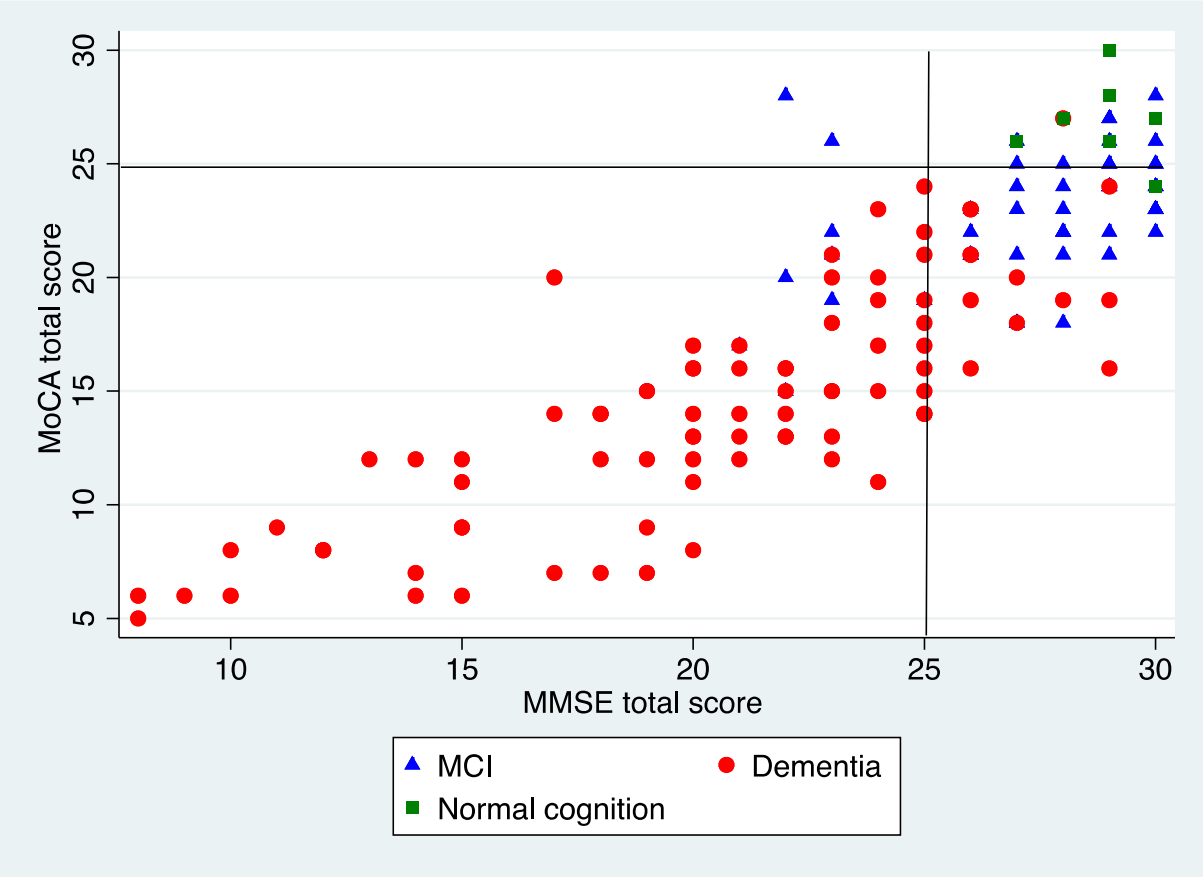
The Means of the Montreal Cognitive Assessment and Mini-Mental State Examination



Notes. MCI, mild cognitive impairment

Figure 3

Montreal Cognitive Assessment and Mini-Mental State Examination Scatter Plots



Notes. MCI, mild cognitive impairment