Reliability and factor structure of the mini-mental state examination (MMSE) among older adults in Jamaica

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Abstract. The Mini-Mental Status Examination is the most commonly used and widely applied test for assessment of cognitive impairment and memory problems. This paper examines reliability-related characteristics and factor structure of the MMSE tool in older persons (age 60 years and over) in a Caribbean country, Jamaica. In 2012, a nationally represented sample of 2943 persons aged ≥60 years were selected using a two-stage cluster sampling technique. MMSE screening tool was administered to eligible participants (2742) to assess cognitive function. Reliability analysis was performed generating inter-item, item-total correlations and standardized Cronbach's alpha values. Exploratory factor analysis elucidated the factor structure of the MMSE instrument. The variation of factor score (composite sub-test scores) with MMSE score was also examined. The Cronbach's alpha coefficient of the MMSE instrument was 0.742, and item-total correlations varied from 0.2 to 0.5. On factor analysis, three factors ('executive functioning,' 'memory' and 'attention') were extracted, which accounted for 32.9% of the total variance in MMSE scores. The variation of factor scores with total MMSE score revealed pattern suggesting that sensitivity of the instrument pivots around MMSE score 18. The MMSE is considered as a reliable instrument for this study and has a three-factor structure. The 3-factor structure parallels recognized dimensions of neurocognitive ability. The established factor structure provides context and understanding, which can aid clinicians and researchers in interpreting data obtained from the use of the MMSE.

Keywords: reliability, factor analysis, Jamaica.

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Abstracto. El Examen del Estado Mini-Mental (EEMM) es la prueba más común y ampliamente utilizada para evaluar el deterioro cognitivo y los problemas de memoria. Este documento examina las características relacionadas con la confiabilidad y la estructura de factores de la herramienta EEMM en personas mayores (de 60 años o más) en el país caribeño, Jamaica. En 2012, se seleccionó una muestra representada a nivel nacional de 2943 personas más de 60 años utilizando una técnica de muestreo conglomerada en dos etapas. La herramienta de detección EEMM fue administrado a los participantes elegibles (2742) para evaluar la función cognitiva. El análisis de confiabilidad se realizó generando correlaciones entre ítems, ítems totales y valores alfa estandarizados de Cronbach. El análisis factorial exploratorio dilucidó la estructura factorial del instrumento EEMM. También se examinó la variación del puntaje del factor (puntajes compuestos de subprueba) con el puntaje EEMM. El coeficiente alfa de Cronbach del instrumento EEMM fue de 0.742, y las correlaciones ítem-totales variaron de 0.2 a 0.5. En el análisis factorial, se extrajeron tres factores ("funcionamiento ejecutivo", "memoria" y "atención"), que representaron el 32,9% de la varianza total en las puntuaciones EEMM. La variación de las puntuaciones de los factores con la puntuación EEMM total, reveló un patrón que sugiere que la sensibilidad del instrumento gira alrededor de la puntuación EEMM 18. El EEMM es un instrumento confiable para usar en nuestro entorno de estudio y tiene una estructura de tres factores. La estructura de 3 factores es paralela a las dimensiones reconocidas de la capacidad neurocognitiva. La estructura de factores establecida proporciona contexto y comprensión, lo cual pueda ayudar a los médicos e investigadores a interpretar los datos obtenidos del uso del EEMM.

Palabras claves: Fiabilidad, análisis factorial, Jamaica.

Introduction

The Mini-Mental Status Examination (MMSE) is the most commonly used and widely applied test for assessment of cognitive impairment and memory problems in clinical medicine and geriatrics (Bour, Rasquin, Boreas, Limburg, & Verhey, 2010; Elhan et al., 2005). There has however been debate and criticisms about its broad applicability in multifarious cultural settings and in linguistically disparate patients. There have also been questions concerning its performance among people of low education status and its ability to identify persons with very mild cognitive difficulties (Carnero-Pardo, 2014).

The MMSE is a brief 11-item screening tool that provides a quantitative assessment of cognitive impairment (Folstein, Folstein, & McHugh, 1975). The tool evaluates performance related to orientation to time and place, immediate recall, short-term verbal memory, calculation, language, and construct ability. The score is the number of correct items, with a maximum total score of 30. The component domain scores with regard to items are: Orientation (total points = 10), Registration (total points = 3), Attention and calculation (total points = 5), Recall (total points = 3), and Language (total points = 9). Generally, a score of 23 or less is deemed indicative of the presence of cognitive impairment (Ruchinskas & Curyto, 2003).

An updated scheme for interpreting scores with regard to level of impairment has been outlined by Folstein, Folstein and Fanjiang (2001) as : ≥ 27, none; 21-26, mild; 11-20, moderate; ≤10, severe. A refinement of an earlier rubric by Tombaugh & McIntyre (1992) where the categories 24-30, none; 18-23, mild; and 0-17, severe, were stipulated. However, the trust placed in the results obtained and their subsequent interpretation is inter alia dependent on reliability of the instrument; reliability being the degree to which an assessment tool produces stable and consistent results (Leech, Barrett, & Morgan, 2015). Internal consistency reliability is a measure of reliability used to evaluate the degree to which different test items that probe the same construct produce similar results (ibid.). If an assessment tool is reliable, one can be confident that repeated or equivalent assessments will provide consistent results (ibid.). Attention to reliability issues is especially important when using the results of an assessment to make decisions about clinical and social care.

Studies indicate variations in the reliability of the MMSE screening tool as reflected by Cronbach's alpha, a commonly recognized measure of the internal consistency (reliability) of scale or tool items (Creavin et al., 2016; Hopp, Dixon, Grut, & Bäckman, 1997; Jorm et al., 1988; Kabátová, Puteková, Martinková, & Súkenníková, 2016). Possible values of Cronbach's alpha generally range between 0 ('no reliability') and 1 ('perfect reliability'), but if items on a scale or tool are in systematic disagreement, negative values may be obtained (Leech, Barrett, & Morgan, 2015). Values above 0.7 are generally considered acceptable with greater reliability as values increase (George & Mallery, 2003). Low values for Cronbach's alpha have been cited for the MMSE instrument; 0.54 among educated (> 8th grade) (Jorm et al., 1988). In a study among adults without dementia who were over the age of 75 years, Hopp, Dixon, Grut, & Backman (1997), reported Cronbach's alpha to vary between 0.31 and 0.52. On the other hand, higher and more desirable values such as 0.75 (Elhan et al., 2005), 0.78 (Kabátová et al., 2016), 0.82 (Ong et al., 2016) and 0.96 (Foreman, 1987) have been documented. These latter studies were conducted respectively in Turkey among acute brain injury patients, Slovakia among geriatric patients, China among patients with schizoaffective disorders, and the USA in hospitalized medical-surgical patients age 65 years and over. Overall, these observations point to the need to establish reliability of the MMSE for the local populations and specific contexts in which the instrument is used. Furthermore, performance of the tool may be affected by variables such as age, education, gender, socioeconomic status, culture, language and ethnicity and test location (for example, home versus hospital) (Li, Jia, Yang, & Moreau, 2016; Norris, Clark, & Shipley, 2016; Ridha & Rossor, 2005).

It is therefore useful to evaluate various aspects of the psychometric properties of the MMSE tool in any population in which it is being used. Although the performance of the MMSE screening tool among older persons in Jamaica with respect to sensitivity, specificity and receiver operating characteristics (ROC) parameters has been recently reported (James et al., 2019), a search of peer-reviewed literature found no published reports or details on attributes related to reliability/internal consistency of the tool in Jamaica or the Anglophone Caribbean. Given projected increases in cognitive impairment and dementia in the region (ADI/Bupa, 2013), with the likelihood of greater dementia and cognitive impairment screening, coupled with rapid population ageing (Quashie, 2017), it is imperative that reliability of this widely used tool is be established. This paper examines reliability related characteristics of the MMSE tool in older persons (age 60 years and over) in a Caribbean country, Jamaica. It specifically reports Cronbach's alpha and item-total correlations in the aforementioned population for the MMSE tool. The factor structure of the instrument when administered in the local population is also explored for comparison with previously reported and established domains.

Method

In 2012, 2943 persons aged 60 years and above in Jamaica constituting a nationally representative sample were surveyed. Data collected during the study pertained to health, lifestyle, and socio-economic aspects of older adults in Jamaica. The study employed a two-stage cluster sample with a probability proportional to size (PPS) to obtain participants for the survey. Parish enumeration districts and households were first- and second-stage cluster units respectively with subsequent selection of eligible participants age 60 years and older. Details of methodological approach and procedures have been published elsewhere (Mitchell-Fearon et al., 2014).

Face-to-face interviews were conducted with study participants. A structured and pre-coded questionnaire elicited socio-demographic information, and the MMSE screening tool was administered to assess cognitive function. From the sample of 2943, 161 persons (approximately 5%) were unable to do the test due to severe illness or physically debilitation or known neurological disease (e.g., severe Parkinson's disease). Mini-Mental Status Examination scores were determined for the remaining 2782 persons.

The MMSE data for the 11 questions of the instrument were entered into a SPSS database (Statistical Package for the Social Sciences, version 19). Reliability analysis was performed generating Cronbach's alpha values as well as inter-item and item-total correlations. Overall Cronbach's alpha based on standardized items was preferentially reported as recommended by Gliem & Gliem, (2003) and Santos, (1999) as the 11 individual items are not scaled the same. For example, the 'Read and Obey' item has - possible scores of 0-1 while the 'Serial 7's' item has possible scores of 0-5.

Given that there are 11 items on the MMSE instrument, an inter-item correlation matrix produces multiple (55 distinct) correlation coefficients; each attempting to capture the relationship between each possible pair of the 11 different items. The data from items on the MMSE tool was subject to principal axis factor analysis (PA) using Varimax rotation; allowing for the aforementioned large amount of information generated to be distilled into a few components that succinctly capture and convey the main constructs which underlie these items in our local context. Values for the determinant (0.178), Keiser-Meyer-Olkin test of sampling adequacy (0.81), Bartlett's test of Sphericity ($p<0.001$) confirmed that criteria for factor analysis were met. Items (subtests) correlated with each other without multicollinearity.

Exploratory factor analysis was done to identify and generate composite scores for factors underlying the MMSE instrument used. Factors with primary factor loading or cross-loadings of 0.4 were used to elucidate the simple factor structure of the MMSE instrument: items being clustered into groups defined by their highest factor loadings.

A scree plot was also used to identify the number of factor components that should be retained in the emergent simple factor structure by identification of the pattern of eigenvalue decline. Consistent with convention, only components with eigenvalues one or greater were retained (Field, 2005; C. H. James, David, & Vida, 2004).

For each respondent, a factor score was generated by summing the score obtained for the items that constitute the factor. The variation of factor score with MMSE score was subsequently examined for factors identified and retained.

Results

There was a total of 2782 participants in the study, with the majority (51.6%) being females. Almost 44% of participants were between the ages of 60-69 years, those in the age categories 70-79, 80-89 and ≥ 90 years accounted for 33.7% (n=936), 18.7% (n=519) and 3.3% (n=93) respectively. The majority (77.6%, n=2144) of participants had primary level education or below, while 12.4% had secondary level education. The remaining portion (10%, n=275) had post-secondary or tertiary level education. Approximately 76% of respondents had one or more doctor-diagnosed chronic disease.

Descriptive statistics for the individual items (subtests) of the MMSE instrument administered to the sample are displayed in Table 1. Respondents generally were able to complete most subtests successfully as highlighted by the relatively high means. Exceptions were those tasks related to attention and calculation, copying design/drawing and recall of three words.

Table 1: Mean score and standard deviation for MMSE items (n=2782)

Items (Subtests)	Possible Score Range	Mean	Std. Deviation
Orientation – time	0 – 5	4.265	1.194
Orientation – place	0 – 5	4.693	0.815
Registration - 3 words	0 – 3	2.895	0.456
Attention and calculation	0 – 5	2.424	2.112
Recall of 3 words	0 – 3	1.325	1.102
Naming of objects	0 – 2	1.912	0.370
Repetition	0 – 1	0.890	0.313
Following/effecting three-stage command	0 – 3	2.692	0.814
Read and obey	0 - 1	0.753	0.432
Write a sentence	0 - 1	0.694	0.461
Copy design/drawing	0 - 1	0.539	0.499

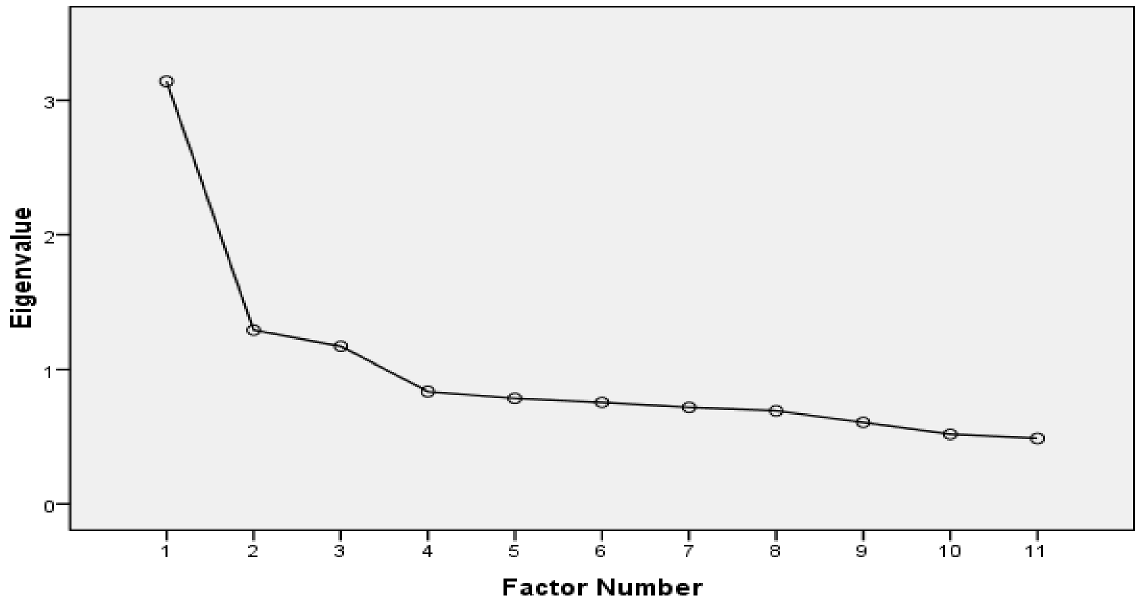
The Cronbach's alpha coefficient of the MMSE instrument based on standardized items was 0.742, and item-total correlations varied approximately from 0.2 to 0.5 (Table 2). Of these item-total correlations (standardized or not) 72.7% were approximately 0.4 and above (rounded to one decimal place). Lower item-total correlations were observed for the items pertaining to 'recall of three words', 'naming of objects' and comprehending/effecting 'the three-stage command'. Each individual item would result in lower or approximately the same Cronbach's alpha if it was deleted, suggesting that all items should be kept as part of the scale.

Table 2: Item-Total correlations of the MMSE tool in persons 60 years and over, Jamaica

Item	Item-Total correlation	Item-Total correlation (standardized)	Cronbach's Alpha if Item deleted (standardized)
Orientation- Time	0.500	0.493	0.708
Orientation -Place	0.426	0.458	0.713
Registration- 3 words	0.369	0.395	0.722
Attention and calculation (serial '7s')	0.430	0.420	0.719
Recall of 3 words	0.253	0.214	0.746
Naming of objects	0.275	0.316	0.733
Repetition	0.353	0.383	0.724
Follow/effect three-stage command	0.229	0.293	0.736
Read and obey	0.407	0.446	0.715
Write a sentence	0.408	0.445	0.715
Copy design/drawing	0.394	0.406	0.720

On factor analysis, three factors were extracted. These three factors had eigenvalues (an indicator of explained variance) greater than 1 suggesting that they explain more information than just what a single item would have explained. The scree plot below (Figure 1) corroborates this observation showing that after these three factors, the curve flattens, and differences between eigenvalues diminish and values are less than 1.

Figure 1: Scree plot for the MMSE among community dwelling older adults, Jamaica



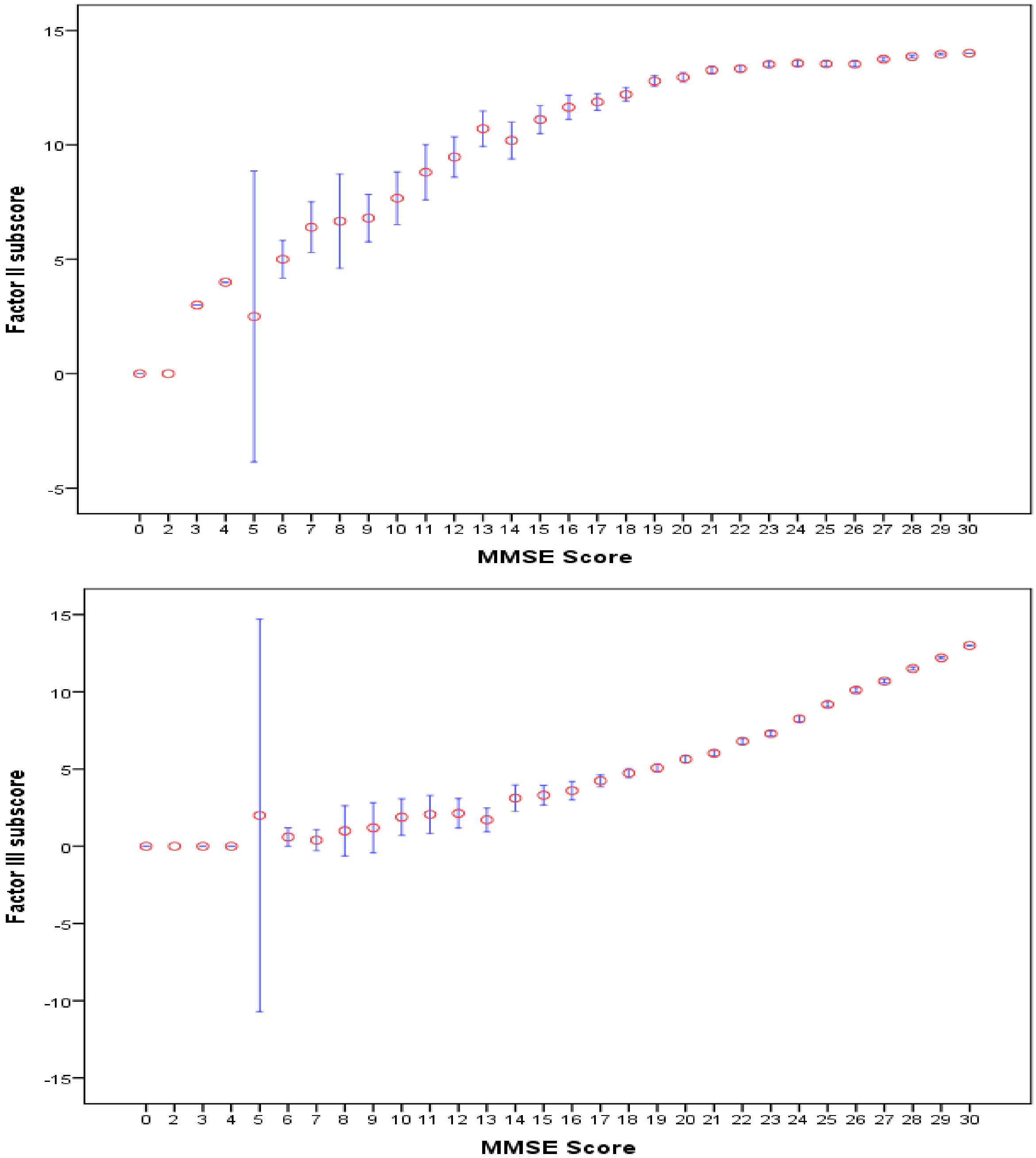
The three identified factors explain approximately 32.9% of the total variance in MMSE score. The first (Factor I), the second (Factor II) and the third (Factor III) account for 12.3%, 11.5% and 9.1% of variance respectively. The factors and their loadings are presented in Table 3. Factor loadings > 0.4 are marked in bold. Table 3 also displays the communalities which ranged from 0.175 – 0.503 and reflect the proportion of variance in each item that can be explained by the three retained factors.

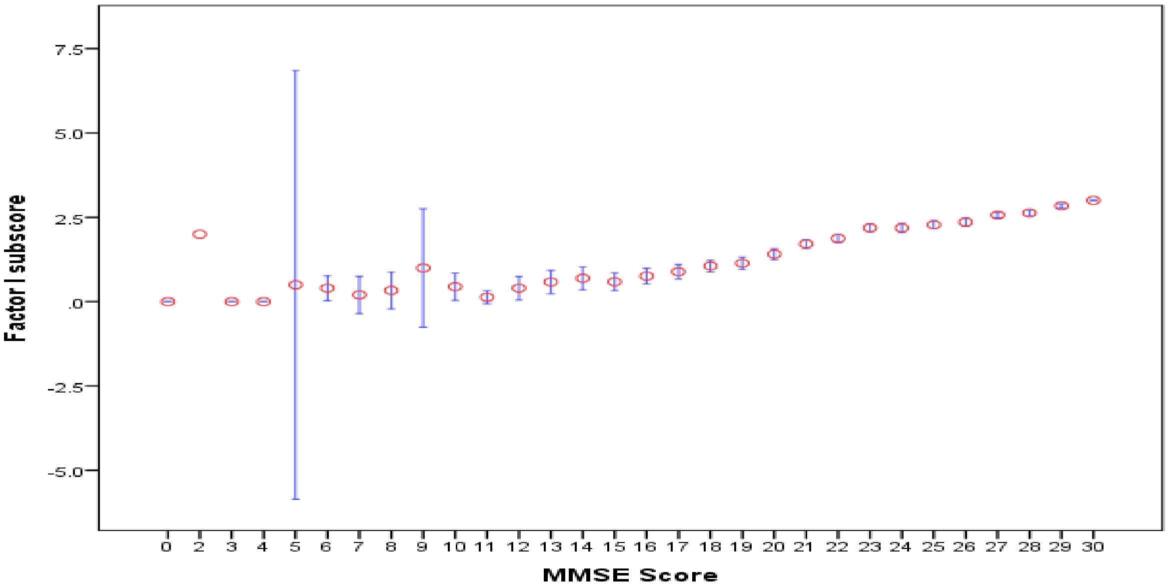
Table 3: Varimax Rotation Factor Matrix for the factor structure of the 11 item MMSE instrument for older adults, Jamaica

	Factor			Communality
	I	II	III	
Item				
Write a sentence	.680	.140	.144	.503
Copy design/drawing	.582	.103	.174	.379
Read and Obey	.554	.255	.100	.382
Orientation –Place	.064	.545	.365	.434
Following/effecting 3-stage command	.183	.456	-.074	.247
Registration- 3 words	.058	.455	.281	.289
Naming of Objects	.160	.434	.012	.214
Repetition	.111	.401	.245	.234
Orientation – Time	.191	.302	.579	.463
Recall of 3 words	.085	.000	.410	.175
Attention and calculation (serial '7s')	.342	.124	.402	.294

Factor I, comprises three items which relate to psychomotor and sequencing aspects of cognition and reflect the ability to plan and execute a goal. This is now labelled 'Executive functioning'. Factor II includes five items which appear to relate to short term and immediate memory. This factor is now labelled 'Memory'. Factor III is composed of three items which predominantly pertain to attention and concentration. This is now labelled 'Attention'. For each of the three factors identified, the variation of factor scores with total MMSE score is shown in Figure 2. Accompanying 95% confidence intervals for each factor score is also displayed. For Factor I, scores generally remained flat with a slight increase after MMSE score of 18. For Factor II, there was a positive correlation between Factor II scores and total MMSE score. There was a notable increase in Factor II scores as MMSE scores increased up to MMSE score of 18, after which, the scores generally remained constant. With regard to Factor III, there was a marginal change in scores as MMSE increased up to MMSE score of 18, after which, there was a sustained increase in factor scores. For all three factors, 95% confidence intervals were relatively narrow and precise, except for MMSE score five as only two participants had a score of five.

Figure 2: Variation of factor score with total MMSE score





Discussion

Establishing reliability is an acknowledged critical step for instruments used in research. For the MMSE in our studied population, Cronbach's alpha was 0.742. This, according to the popularly used scale by George and Mallery (2003) implies an acceptable reliability and moderate internal consistency of the MMSE tool (George & Mallery, 2003). Previous studies have reported comparable Cronbach's alpha values of 0.75, 0.74 and 0.80 respectively (Awan et al., 2015; Elhan et al., 2005; Iatraki et al., 2017); the latter two from Pakistan (a developing country) and from a rural population of relatively low educational status in Greece respectively. Moderate internal consistency of the MMSE tool in our study is corroborated by the fact that 72.7% of the item total correlations was above 0.4. De Vaus (2013) recommend item total correlation values of 0.40 and above (De Vaus, 2013) and Carmines & Zeller (1974) advocate having at least 50% of the item total scores being in the range of 0.30 to 0.70 (Carmines & Zeller, 1974).

Factor analysis of the present study resulted in three factors which we designate 'Executive functioning', 'Memory' and 'Attention'. The three factor solution parallels results of other studies such as Shyu & Yip (2001) and Shigemori, Ohgi, Okuyama, Shimura, & Schneider (2010) which had similar structure. For example, compared with Shyu and Yip (2001) our Factor I 'Executive functioning' mirrored the 'Complex processing' factor in that study and included the items (subtests) 'Write a sentence', 'Read and Obey' and 'Copy design/drawing'. The Factor II 'Memory' was analogous to their 'Simple processing' which included naming, command, repetition and registration, and reflects processes related to short term memory, storage and simultaneous processing. The Factor III 'Attention' was equivalent to their Attention/Memory factor and consequently is concerned with items such as spelling, arithmetic and attention to calculation. Orientation in time also loaded on Factor III. It may appear counterintuitive, however, it is known that orientation in time is associated with functions in the pre-frontal cortex (Gozlan, 2013; Rao, Mayer, & Harrington, 2001), a region which regulates attention (Arnsten, 2009).

The triple factor structure was deemed optimal because of: evident leveling off of eigenvalues below one after three factors and because the three-factor grouping facilitated represented a simple structure that facilitated logical interpretation and characterization of the factors; the primary purpose of factor analysis. Approximately one third of the variance in MMSE subtests was explained by these three factors. Other studies with three factor extractions have reported percentage of total variance explained ranging from 44.6% - 85% (Brugnolo et al., 2009; Fillenbaum, Heyman, & Haynes, 1987; Shigemori, Ohgi, Okuyama, Shimura, & Schneider, 2010). The wide variation in variance explained across studies and the contrast with our study could be due to a number of factors. The differences in clinical profile of the populations studied and second, differences in educational level. In this study, subjects were community dwelling older persons from the general population compared to other studies (Brugnolo et al., 2009; Fillenbaum et al., 1987; Shigemori et al., 2010) which were confined to groups with specific morbidities for example, Alzheimer's disease, hospitalized stroke patients and patients with mild cognitive impairment (MCI). Self-care ability influences 'attention' and 'simple processing' (memory) (Shyu & Yip, 2001). Education level can impact the responses obtained on the MMSE and the percentage of total variance explained. Educational level has been associated with complex processing ability (akin to 'executive processing' in our study) accounting for as much as 88% of its variance (Shyu & Yip, 2001).

This study's elucidation of a three-factor structure may have implications for existing and future shortened versions of screening tests for cognitive impairment, example the Mini-Cog© test. Shortened tests ought to reflect these three factors or domains in their construction. The Mini-Cog© test would arguably be very useful in our local setting as its three constituent items are aligned to elements from each of our three factors: three item registration (Factor II), three-word recall (Factor III) and clock drawing (Factor I). The World Health Organization (2008) 'Age Friendly Primary Health Care Centres Toolkit' is a ten-minute comprehensive screening tool developed to work in a number of countries including Jamaica (World Health Organization, 2008) This tool utilizes registration and recall of three words for preliminary rapid screening of memory function with subsequent detailed screening using the MMSE, as necessary. Registration and recall of three words are related to Factors II and III of this study respectively. Future efforts for improving this instrument may involve including an item from our Factor I domain.

The pattern of variation of factor scores with total MMSE scores provides additional insight on the way its constituent items (sub-test) collectively influence MMSE scores and subsequent screening results. The pattern for Factor I with total MMSE scores shows a subtle but evident decline from higher scores, until MMSE score of 18 and was generally flat for the lower scores thereafter. This factor appears to be useful for detecting early decline. Factor II remained relatively constant at scores above MMSE score of 18, but displayed a sharp linear decline with scores below MMSE score 18. Factor II and its constituent sub-tests appear to be relatively insensitive to early cognitive decline and mild impairment, but effectively identifies deterioration in MMSE scores and cognitive function subsequently. Previous authors have noted that the items which comprise Factor II are concerned with verbal skills that arise from entrenched knowledge, and these are conserved in early dementia and cognitive decline, explaining the relative insensitivity at higher MMSE scores (Brugnolo et al., 2009; Feher et al., 1992). Factor III was highly sensitive to decline in higher MMSE scores and thus may be useful in efforts to identify early or mild cognitive impairment.

Each factor maximizes sensitivity across different ranges of scores. Taken collectively, they constitute a robust instrument and the MMSE as a tool is likely to be useful in our, and similar settings. In this study, changes in patterns seem to pivot around MMSE score of 18. Previously published findings utilizing data derived from the same sample of participants in this study has noted that the MMSE score cut-point which maximizes sensitivity and specificity was 18/19 (K. James et al., 2019). Graphical analysis of the relation between factor score and total MMSE score appears to indicate and corroborate optimal cut-points.

It was recognize that education level may influence emergent factor structure and item performance (Vissoci et al., 2019). In this study, participants predominantly had low educational level, with 78% achieving primary level education and below as their highest level of schooling; consequently, effects of education level could not be substantively addressed. Nevertheless, this study proposed many strengths. A nationally representative sample was used, and the sample size was large. The study provides new information on factor structure and reliability of the MMSE in the Caribbean region - the second most rapidly ageing region of the world. Furthermore, it adds to the global body of literature being one of the few studies that have examined and reported on the variation and relationship of factor scores and overall MMSE scores.

Conclusion

The MMSE is a reliable instrument for use in our study setting and optimally has a three-factor structure (‘executive functioning,’ ‘memory’ and ‘attention’). The 3-factor structure parallels recognized dimensions of neurocognitive ability. There is variation in the relationship of individual factors across total MMSE scores. The established reliability and factor structure provides greater contextual understanding of the psychometric attributes of the MMSE, which can aid clinicians and researchers in interpreting data derived from its use.

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