PSYCHOMETRIC PROPERTIES OF THE MINI-MENTAL STATE EXAMINATION IN PATIENTS WITH ACQUIRED BRAIN INJURY IN TURKEY

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Objective: To evaluate the psychometric properties of Mini-Mental State Examination (MMSE) in patients with acquired brain injury in Turkey.

Methods: A total of 207 patients with acquired brain injury were assessed. Reliability was tested by internal consistency and the person separation index; internal construct validity by Rasch analysis; external construct validity by correlation with cognitive disability; and cross-cultural validity by differential item functioning analysis compared with Italian MMSE data.

Results: Reliability was adequate with a Cronbach’s alpha of 0.75 and person separation index of 0.76. After collapsing some categories, and adjustment for differential item functioning, internal construct validity was supported by fit of the data to Rasch model. Differential item functioning for culture was found in 2 items and after adjustment, data could be pooled between Turkey and Italy. External construct validity was supported by expected associations.

Conclusion: The Turkish version of the Mini-Mental State Examination can be used as a cognitive screening tool in acquired brain injury. Cross-cultural validity between Italy and Turkey is supported, given appropriate adjustment for differential item functioning. However, shortfalls in reliability at the individual level, as well as the presence of differential item functioning suggest that a better instrument should be developed to screen for cognitive deficits following acquired brain injury.

Key words: Mini-Mental State Examination, Rasch analysis, differential item functioning, outcomes, cross-cultural, cognition, rehabilitation.


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INTRODUCTION

Assessment of cognitive function is essential in neuro-rehabilitation practice. As cognitive impairment can limit functional gains during inpatient rehabilitation, the early and follow-up assessment of cognitive skills is crucial in the management of brain-injured patients (1, 2).

The Mini-Mental State Examination (MMSE), first introduced by Folstein et al. in 1975 (3), has been suggested as a valuable, consistent and rapid cognitive screening instrument for routine initial assessment in neurological patients (4). It comprises 6 domains of cognition: orientation, registration of new information, attention and calculation, recall, language and visuospatial construction. These domains have a variable number of items giving a total of 11 items for the scale. The items have a different number of response categories ranging from dichotomous to a 6-category response. Thus 11 items are summed to give a maximum score of 30. Several studies suggest an optimum cut-off point of 23/24 to separate patients with cognitive impairment from those who are cognitively intact (3, 5, 6).

The MMSE is one of the most widely used cognitive screening instruments in Europe (7), and has been used within different cultural and ethnic groups and translated into many languages (8–10). Factors such as language, low levels of education and ethnic origin can adversely affect performance on tests of cognitive functioning (5, 8). In order to eliminate bias, some authors provide MMSE norms specific for age and education in non-disabled adults (5, 9–11).

While the MMSE has been used in neuro-rehabilitation settings as a screening tool for research purposes (1, 12), only the reliability and validity for those with mild dementia has been established for the Turkish population (13). Thus as the validity of this instrument has not been demonstrated for those with brain injury, the aim of this study was to evaluate its psychometric properties in patients with acquired brain injury in Turkey and to decide its feasibility for clinical use. This becomes particularly important in the context of recent findings showing the lack of validity of the MMSE in a normal population in Turkey (14). In addition, its potential for use in a cross-cultural setting was also considered.

The Rasch measurement model (15) was used to evaluate the MMSE and identify implications for clinical practice. This mathematical measurement model is increasingly used to evaluate existing scales and to examine issues such as cross-cultural validity (16).
METHODS

Translation procedure

The original MMSE was translated into Turkish by 3 bilingual professionals. Two of these were medical doctors, and were regarded as “informed” translators. The third translator was an English teacher. Inconsistencies in the translations were resolved by discussion among the translators. Most of the items on the MMSE could be translated directly and used in Turkish. The standard scoring and administration procedures for the MMSE were followed (6).

Three items needed modification:

- Registration: among the words “Apple, penny, table” in the original MMSE, penny has been modified. As the Turkish equivalent has 2 words (bozuk para), “money” (in Turkish, para) is used instead.
- Language/repeat phrase: as there is no suitable Turkish counterpart for the repetition phrase “no ifs, ands, or buts”, the phrase has been translated into Turkish literally as egerler, veler veya amalar yok.
- Language/3-step command: the third stage of 3-step command in the original version “Take this paper in your right hand, fold it in half and put the paper on the floor” has been modified to “rest the paper on your legs”, since “put the paper on the floor” is inappropriate for some patients.

Once translated, field-testing for face validity was performed in a group of 30 literate patients with variable educational levels with various musculoskeletal disorders such as osteoarthritis, low back pain and radicular pain syndrome. At this stage, most patients found the “repeat phrase” item difficult to understand. However, no direct conceptual equivalent could be found and so a direct literal translation was retained.

Patients

The study was performed in the Department of Physical Medicine and Rehabilitation at the Medical School of Ankara University, Turkey, from November 2000 to September 2003. A total of 207 patients with consecutive acquired brain injury who had been admitted for rehabilitation were included in the study. Patients with significant difficulties in language expression or comprehension or with a history of previous dementia were excluded. For the cross-cultural validation, Italian data were obtained from the stroke sample of a European study of the use of rehabilitation outcome measures (17).

Reliability

The internal consistency of the adapted version of the MMSE was evaluated first. The internal consistency of an instrument is an estimate of the degree to which its constituent items are interrelated, and is assessed by Cronbach’s alpha coefficient (18). Reliability was also evaluated with the person separation index from the Rasch analysis (see below). This is similar to coefficient alpha, but uses the metric latent trait in place of the summed score. A person separation index of 0.7 and above is consistent with the scale being able to differentiate at least 2 strata of patients (19) and is considered the minimum requirement for measurement.

Internal and cross-cultural validity

Internal validity is concerned with the integrity of the defined construct (20). The internal construct validity, and the cross-cultural validity of the Turkish adaptation of the MMSE were assessed using the Rasch measurement model (15, 21). The Rasch model is a unidimensional model which asserts that the easier the item (task) the more likely it will be passed, and the more able the person, the more likely they will pass an item (or be able to do a task) compared with a less able person. The Rasch model is used extensively within the medical outcomes field to evaluate whether or not items are “biased” for key subgroups such as age or gender (Differential Item Functioning (DIF)) and whether or not items are distributed such that a mean of zero and standard deviation of 1 indicate perfect fit to the model. A chi-square interaction statistic determines the invariance of the scale across the trait (mental status), and should show a non-significant deviation from model expectation. Individual item chi-square statistics should also indicate non-significant deviations, and item residual statistics should be within the range \( \pm 2.5 \) (21).

Within the framework of Rasch measurement, the scale should work in the same way, irrespective of which group is being assessed. Thus, in the case of mental status, the probability of a person affirming an item (or category), at any given level of mental status, should be the same for younger or older people, men and women, Turks and Italians, and so on. Items that do not yield the same item response function for 2 or more groups display DIF and violate the requirements of unidimensionality (26). Consequently, every item is checked for DIF by age, gender and education and, for the cross-cultural analysis, by country.

Finally, person-item deviation residuals (the residual for each person on every item) were examined with Principal Components Analysis (PCA) for associations, which may be indicative of the breach of the assumptions of local independence. Thus after the “Rasch” factor (i.e. the underlying trait) should be no discernible pattern left in the residuals. The absence of such patterns, taken with adequate fit to the Rasch model, supports the unidimensionality of the scale.

External construct validity and responsiveness

External construct validity is concerned with whether or not the scale measures what it intends. It is assessed through convergent validity with the Functional Independence Measure (FIM) cognitive scale, previously adapted for use in Turkey (27). Although a measure of disability rather than impairment, a moderate correlation would be expected (1). Responsiveness is evaluated through the Effect Size (28).

Sample size and statistical software

For the Rasch analysis it is reported that a sample size of 150 patients will estimate item difficulty, with a 95% confidence interval of \( \pm 0.2 \) logits (29). This sample size is also sufficient to test for DIF where, at a 0.01 a difference of 0.5 within the residuals can be detected for any 2 groups with \( \beta \) of 0.20. Bonferroni corrections are applied to both fit and DIF statistics due to the number of tests undertaken (30). A value of 0.004 is used throughout.

The Wilcoxon signed rank test was used for evaluating change over time and Spearman’s rank correlation for associations between instruments. Statistical analysis was undertaken with SPSS-11, and Rasch analysis with the RUMM2020 package (31).

RESULTS

Patients

The mean age of the 207 Turkish patients was 57.9 years (standard deviation (SD) 15.3), 64% were men, and patients had a mean time since injury of 152.3 days. The cause of the acquired brain injury was predominately stroke (84%) and almost 1-in-8 patients were illiterate. In addition, the data from 105 stroke patients in Italy with a mean age of 71.9 years (SD 12.0) were included for cross-cultural analysis, 61% of whom were women. There was a lack of gender equivalence between the 2 samples.
Reliability

Internal consistency of the Turkish version of MMSE was adequate at the group level with Cronbach’s alphas of 0.75 and 0.70 at admission and discharge, respectively. The person separation index of 0.76 on admission indicates that the scale had the ability to differentiate 2 groups of patients (19).

Internal construct validity

Initially, many items displayed disordered thresholds, necessitating collapsing of categories. For example, while the item “orientation time” displayed ordered thresholds, in that each threshold demonstrates an increasing level of the trait of mental state, the item “attention” failed to display ordering such that it was necessary to dichotomize the item. In total 6 items displayed disordered thresholds and were re-scored. Following this, all items apart from “recall” were found to fit the model (given a Bonferroni adjustment fit level of 0.004) (Table I). Overall mean item fit was –0.362 (SD 1.465) and mean person fit was –0.224 (SD 0.515). However, the item-trait interaction was significant, suggesting that cumulatively, across the scale, there was a lack of invariance of items (chi-square (df = 22) 52.5, p = 0.00026). The person separation index was satisfactory (0.764) indicating the ability of the scale to differentiate more than 2 groups of patients (19). Overall, the scale was well targeted in that the measurement, expressed through the distribution of the thresholds, covered all levels of patients across the trait (Fig. 1). With a mean person score of 0.915, patients in this study displayed a slightly higher average mental status than the average item difficulty.

The “attention and calculation” item displayed DIF by both age and education. The items “recall”, “language/comprehension” and “language/sentence construction” displayed substantive DIF for educational level, with the last 2 showing that the illiterate group were scoring below expectation (Fig. 2). Due to the low number of illiterate patients, these 3 items were first grouped into 1 item (that is their responses were added together to avoid extreme scores), and the analysis re-run with 9 items (8 originals, plus 1 item made up of the sum of scores from the 3). Furthermore, the new grouped item was split such that 1 new item related to just those who were illiterate, and the other items to the other education groups, making 10 items in all. Following this modification, good fit to the Rasch model was attained. Overall mean item fit was –0.437 (SD 0.912) and person fit of –0.252 (SD 0.481). The item-trait interaction was now non-significant, supporting the invariance of items across the scale (chi-square (df = 19) 37.8, p = 0.007). The person separation index was 0.77, indicating the ability of the scale to differentiate at least 2 groups of patients (19).

Finally, PCA analysis of residuals showed no discernible pattern, with the first factor taking 18% of the variation amongst the residuals, so supporting the assumption of unidimensionality.

**Table 1. Fit of Mini-Mental State Examination to Rasch model (after rescoring)**

<table>
<thead>
<tr>
<th>Item</th>
<th>Location</th>
<th>SE</th>
<th>Residual</th>
<th>Chi-square</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orientation time</td>
<td>0.24</td>
<td>0.07</td>
<td>–1.90</td>
<td>3.23</td>
<td>0.357</td>
</tr>
<tr>
<td>Orientation place</td>
<td>–0.03</td>
<td>0.12</td>
<td>–1.56</td>
<td>6.80</td>
<td>0.079</td>
</tr>
<tr>
<td>Registration</td>
<td>–3.95</td>
<td>0.54</td>
<td>–0.27</td>
<td>0.88</td>
<td>0.829</td>
</tr>
<tr>
<td>Attention and calculation</td>
<td>1.42</td>
<td>0.16</td>
<td>–1.36</td>
<td>12.32</td>
<td>0.006</td>
</tr>
<tr>
<td>Recall</td>
<td>1.42</td>
<td>0.09</td>
<td>3.06</td>
<td>17.08</td>
<td>0.001*</td>
</tr>
<tr>
<td>Language naming</td>
<td>–3.53</td>
<td>0.45</td>
<td>–0.01</td>
<td>2.29</td>
<td>0.514</td>
</tr>
<tr>
<td>Language repeat phase</td>
<td>2.91</td>
<td>0.20</td>
<td>1.53</td>
<td>3.40</td>
<td>0.325</td>
</tr>
<tr>
<td>Language 3-step command</td>
<td>–1.44</td>
<td>0.22</td>
<td>–0.64</td>
<td>1.89</td>
<td>0.394</td>
</tr>
<tr>
<td>Language comprehension</td>
<td>–0.49</td>
<td>0.18</td>
<td>–1.00</td>
<td>3.42</td>
<td>0.330</td>
</tr>
<tr>
<td>Language sentence construction</td>
<td>1.39</td>
<td>0.16</td>
<td>–1.13</td>
<td>11.75</td>
<td>0.008</td>
</tr>
<tr>
<td>Copy figure</td>
<td>2.06</td>
<td>0.17</td>
<td>–0.71</td>
<td>13.15</td>
<td>0.004</td>
</tr>
</tbody>
</table>

*Misfitting item. SE = standard error.

**Fig. 1.** Targeting of scale to patient ability (after re-scoring). Person-Item Threshold Distribution (grouping set to interval length of 0.20 making 45 groups).
Cross-cultural validity

The Italian and Turkish stroke data were pooled to test for invariance across cultures. Due to the potential confounding effect of education (for example all illiterates were within the stroke group) only those completing at least middle education in Turkey were included in the analysis. Likewise, because of gender differences between the 2 samples, the absence of DIF by gender was first evaluated for all items. After re-scoring overall mean item fit was $-0.510$ (SD 1.030) and person fit of $-0.200$ (SD 0.424). The item-trait interaction was significant, indicating a lack of invariance of items across the scale for the pooled data (chi-square (df = 33) 66.0, $p = 0.0006$). The person separation index was 0.895, indicating the ability to distinguish 4 groups of patients across the construct (19). Two items “language/repeat phrase” and “attention and calculation” were found to display DIF across the 2 countries. Thus, for example, at the same level of cognitive impairment, Italian patients were more likely to correctly repeat the phrase item than Turkish patients (Fig. 3). The items were split for country and following this, overall mean item fit was $-0.561$ (SD 0.860) and person fit of $-0.229$ (SD 0.454), indicating good fit to model expectation. The item-trait interaction improved although still just significant (chi-square (df = 39) 68.4, $p = 0.003$). Nevertheless no single item displayed significant misfit to the model ($p > 0.004$) and thus the scales can be considered equivalent and, given the split items above, data can be pooled.

External construct validity and responsiveness

The mean MMSE score of the 207 patients at admission was 19.3 (SD 6.1, median: 19, min–max: 4–29). The Spearman correlation between the FIM cognitive scale and the MMSE was 0.60 at admission and 0.53 at discharge, confirming convergent validity with an expected moderate association between cognitive impairment and cognitive disability. However, as expected, a weaker correlation was found between MMSE and FIM motor scale ($r = 0.29$ at admission, 0.30 at discharge). The effect size for the MMSE was 0.60 compared with 0.19 for the FIM cognitive scale. The effect size for the FIM motor scale was 0.74 showing that, as expected, the change in physical function was the greatest.

DISCUSSION

The MMSE is the most widely used screening measure of cognitive impairment. It has the advantages of brevity, ease of administration and high inter-rater reliability. It can easily be incorporated into routine clinical practice and provides a rough and ready evaluation of cognitive function. It has some
limitations, for example in detecting focal deficits and insensitivity to frontal lobe disorders (6, 32). The present study investigates the reliability and validity of the MMSE as a brief cognitive screening test amongst acquired brain injury patients in Turkey. The reliability of the present version was supported with internal consistency at group levels (0.75 and 0.70 at admission and discharge), comparable to other cognitive screening instruments in acquired brain injury (33). However, this level of reliability is disappointing for a screening tool, which is routinely used at the individual patient level.

Internal construct validity of the scale was evaluated by fit to the Rasch model. There was DIF for age and education in item attention/calculation. Moreover, 3 items showed DIF by education. These findings suggested that some of the items were affected by illiteracy and that the scale works differently in the cognitive assessment amongst illiterate people. This influence of age and education on the MMSE has been well documented in other studies (5, 9, 11, 34). Although a cut-off score of 23/24 was initially suggested for distinguishing between impaired and normal subjects, later, it has been suggested that cut-off scores should be adjusted according to age and educational level. Furthermore, population-based norms by age and education have been defined in some countries (5, 10), but the scale has been found to be invalid in a normal population in Turkey (14).

Comparison of the Turkish MMSE with the Italian counterpart found 2 items presenting DIF. DIF in the item “language/repeat phrase” might be due to the fact that the phrase used in Italy was a more common item in that culture compared with the phrase used in Turkey. Thus the cross-cultural adaptation has delivered a scale, which is shown to be similar to that used in Italy. However, this comparison is only available after complex analysis, which would not normally be available outside research groups with the necessary resources. Substantive work on large samples would need to be undertaken to provide the information necessary for comparisons in the absence of such technologies. This experience of this adaptation process is such that the rehabilitation outcome measurement cannot be taken for granted, and that instruments, even when using state-of-the-art adaptation procedures, cannot be considered equivalent without appropriate analysis to test for invariance across cultures. Furthermore, cumulative deficits in the quality of the instrument with respect to its reliability and internal construct validity, including its scoring functions, suggest that the scale is less than ideal when judged against modern psychometric standards. This would suggest that those with data from other countries should re-examine the scale using the same methodology to assess whether or not the same limitations apply elsewhere.

Given this, the external construct validity of the scale was demonstrated by expected associations with physical and cognitive disability. Similar associations have been reported elsewhere (1, 2, 12). The scale has also been shown to have a respectable effect size compared with the FIM cognitive scale.

In conclusion, the Turkish version of the MMSE can be used as a cognitive screening tool in acquired brain injury, given the limitations mentioned above. Its cross-cultural validity has also been established between Italy and Turkey, but only after adjustments for cultural differences. If data are to be pooled across countries then formal tests of invariance must be undertaken before any confidence can be made in the findings. Furthermore, insufficient reliability of the MMSE at the individual level, the lack of discrimination across categories for some items, and the presence of DIF for some items, as well as acknowledged shortfall in the range of cognitive areas covered, suggest that in the medium-term a more comprehensive scale with better psychometric properties should be sought.

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REFERENCES

14. Kucuktalevci AA, Kutlay S, Elhan AH, Tennant A. Preliminary study to evaluate the validity of the Mini-Mental State Examination

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