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Evaluation of a Japanese version of the Mini-Mental State Examination in elderly persons

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Aim: This study aimed to examine the validity and item-response characteristics of the Mini-Mental State Examination (MMSE), which is used for assessing cognitive function, in Japanese older adults.

Methods: Factor analysis and item response analysis were carried out for MMSE responses ($n = 1971$) from older adults living in the community ($n = 1339$) or in a nursing home ($n = 632$), including Alzheimer-type dementia ($n = 330$), vascular dementia ($n = 36$), frontotemporal dementia ($n = 7$), mixed Alzheimer-type and frontotemporal type dementia ($n = 27$), and age-related cognitive decline ($n = 29$). When choosing the cut-off score of 23 points for the MMSE, sensitivity and specificity for each item were calculated.

Results: A three-factor solution was found to be most appropriate by factor analysis: complex processing, simple processing and working memory. The item characteristics curves showed unidimensionality with high reproducibility. We identified a simplified scale comprising 10 items in all participants: “naming”, “three-step command”, “registration”, “repeat a sentence”, “write a complete sentence”, “copies drawing of two polygons”, “orientation to place”, “delayed recall”, “orientation to time” and “serial sevens” tasks. Sensitivity and specificity for both “year” task and “day” task were more than 90% (“year”: sensitivity 92.5%, specificity 96.3%; “day”: sensitivity 92.4%, specificity 91.7%). For the Alzheimer-type dementia patients, the five-factor solution was suggested by factor analysis and the MMSE also had unidimensionality in terms of level of difficulty.

Conclusions: We found that the MMSE had multiple cognitive areas. We showed that the MMSE could be used as an essentially unidimensional measure of cognitive ability and the question about orientation to time might be useful in the simplest assessment to identify cognitive dysfunction. *Geriatr Gerontol Int* 2012; 12: 310–316.

Keywords: factor analysis, internal structure, item response theory, Mini-Mental State Examination, unidimensionality.

Introduction

Because cognitive impairment makes it difficult to carry out activities of daily life, it is important to accurately measure cognitive function in individuals with physical or mental illness. Although detailed assessment instruments, such as the Wechsler Adult Intelligence Scale, might be ideal, such instruments include many

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questions and are time-consuming. Furthermore, older adults, particularly those with physical or mental illness, might not have the attention span required for such assessments. The Mini-Mental State Examination (MMSE) is a short assessment instrument used in such clinical settings.

The MMSE was devised by Folstein *et al.* in 1975 to measure cognitive status in individuals with mental illness.¹ It consists of 30 items formulated as 11 questions, and measures five aspects of cognitive function: “orientation”, “registration”, “attention and calculation”, “recall” and “language”. The maximum score on the MMSE is 30, and a score of 23 or less shows cognitive impairment.

The MMSE has attained widespread use among clinicians and researchers. It is available in many languages and has been validated in each language version. In particular, external construct validity has been described in the literature by comparison with other standardized cognitive or intelligence tests. For example, Folstein *et al.*¹ found a correlation between scores for the MMSE and for the Wechsler Adult Intelligence Scale, thereby showing high external validity of the MMSE.

However, validation of another component, internal structure, has not been well described. The internal structure of the MMSE can be characterized by factor analysis; however, previously reported factor analyses are difficult to compare with one another as a result of differences in sample composition² and in their handling of individual items.^{3,4} Furthermore, many published factor analyses of the MMSE have problems of statistical methodology, such as small sample size.³ Nonetheless, Jones and Gallo⁵ carried out factor analysis of MMSE responses from 8556 community-dwelling older adults in the USA and showed that the MMSE had five factors equivalent to the five aspects described by Folstein *et al.*¹

Japanese versions of the MMSE are available, translated by Mori *et al.*⁶ and Kitamura.⁷ They are often used in clinical settings to assess cognitive function. However, only a few studies on the validity of Japanese MMSE have been published.^{8,9} In the present study, we carried out factor analysis and item response analysis to examine the validity and item-response characteristics of the Japanese MMSE in a Japanese study population including both community-dwelling older adults and individuals living in a nursing home. The responses of Alzheimer’s disease (AD) patients were analyzed to examine the distinction of AD, which is one of the causes of older adults’ cognitive impairment.

Methods

Study population

The present study is part of an epidemiological research project and was approved by the Ethical committee of

the Tokyo Dementia Care Research and Training Center. Participants were individuals who lived in a nursing home in Sugunami and community-dwelling older adults who agreed to participate in the present study. The community-dwelling older adults were drawn from those who underwent a basic health examination at Yokufuukai Hospital; this included the MMSE (Kitamura version). Nursing home residents had completed the MMSE (Kitamura version) as a health check. A total of 1978 respondents were interviewed for the MMSE (Kitamura version) from 2003 to 2006. Those who refused during the interview or were unable to respond to the MMSE (Kitamura version) questions were excluded from the analyses. The final sample for analysis comprised 1971 respondents.

The 1971 participants ranged in age from 60 to 104 years, with a mean of 79.1 years and SD of 7.7; 1372 (69.1%) were female and 599 were male. In terms of living arrangements, 632 (32.1%) were nursing home residents and 1339 (67.9%) lived in the community. The participants who lived in the community were 62–100 years-of-age, with a mean of 76.1 ± 5.8 years; 850 were female and 489 were male. Nursing home residents were 60–104 years-of-age with a mean of 85.3 ± 7.4 years; 522 were female and 110 were male. Of the nursing home residents, 330 had been diagnosed with Alzheimer-type dementia from computed tomography (CT) and clinical assessment, whereas the others had been diagnosed with vascular dementia ($n = 36$), frontotemporal dementia ($n = 7$), mixed Alzheimer-type and frontotemporal-type dementia ($n = 27$) or age-related cognitive decline ($n = 29$).

MMSE measurements

The Japanese version of the MMSE by Kitamura was used to assess cognitive function.⁷ The differences between the original English version of the MMSE and the Japanese version by Kitamura are “orientation to place” tasks and “repeat a sentence” task: “where are we (state) (county) (town) (hospital) (floor)” in English correspond to “where are we (prefecture) (city or town) (hospital) (floor) (district)” in Japanese, “repeat ‘No ifs, ands, or buts’ ” in English corresponds to “repeat ‘We put ones’ efforts all together and pull the rope’ ” in Japanese. All MMSE (Kitamura version) questions were given; no alternatives to “serial sevens” were given. MMSE responses were graded against a maximum of 30 points, based on Kitamura’s translation. Each item of the MMSE (Kitamura version) was coded 1 if the participant responded correctly; otherwise the item was coded 0. Questions to which participants did not respond or stated “don’t know” or the equivalent were given a score of 0. For “registration”, only those able to answer all three words correctly when these words were presented a maximum of six times were given three

points. Therefore, as “registration” was considered one item, we carried out factor analysis for 28 items of the MMSE (Kitamura version).

Statistical analysis

Factor analysis was carried out to examine the inner construction of MMSE (Kitamura version) for two groups: a) all participants; and b) nursing home residents with AD. The unweighted least squares method was used. The axes were rotated with the varimax rotation to increase its interpretability. The eigenvalue-greater-than-1.0 rule was applied to decide the number of factors.

Item response analysis for the 28 MMSE (Kitamura version) items was carried out to examine the relationships among the 28 MMSE (Kitamura version) items. To identify a more simplified and efficient scale, items with less unidimensionality or similarity were deleted. The item characteristic curves were drawn, and Guttman's coefficient of reproducibility (Rep)¹⁰ was calculated. In addition, Jackson's plus percentage ratio (PPR)¹¹ and Nishisato's PPR^{*12} were calculated, because of the limitation of Guttman's Rep; the maximum value is 1.0, and the minimum depends on the difficulty of each item and the minimum value is 0.5. Furthermore, when choosing a cut-off score of 23 points for the MMSE (Kitamura version), sensitivity and specificity for each item were calculated to examine each task compared with the cut-off and to identify the most comparable questions to the 23-point cut-off of MMSE (Kitamura version). SAS ver. 8.0 (SAS Institute, Cary, NC, USA) was used for these analyses.

Results

Population

Among all participants, the total MMSE (Kitamura version) score ranged from 0 to 30, with a mean of 22.1 and SD of 10.0, and nursing home residents with AD: $n = 330$; 295 women and 35 men. Average age in this group was 87.1 years (SD = 6.9) and average total MMSE (Kitamura version) score was 7.9 (SD = 7.3). In addition, average total MMSE (Kitamura version) scores in other dementia groups and the age-related cognitive decline group are as shown: vascular dementia 14.4 ± 7.7 , frontotemporal dementia 20.1 ± 9.2 , mixed Alzheimer-type and frontotemporal type dementia 4.8 ± 4.8 , age-related cognitive decline 26.7 ± 2.2 .

Factor analysis

All participants

Application of the eigenvalue-greater-than-1.0 rule suggested a three-factor solution. The first factor

accounted for 64.8% of the variance, and the subsequent two factors for 9.5% and 4.9% of the variance, respectively.

The factor loadings of each item after varimax rotation are presented in Table 1. For the first factor, all items had positive loadings. This factor had large loadings with “orientation” tasks; “delayed recall” tasks; and the “repeat a sentence”, “read and follow an instruction” and “copies drawing of two polygons” tasks. The second factor had large loadings with “registration”, “naming” and “three-step command” tasks, and the third factor had a large loading with “serial sevens” tasks. The first factor was complex processing, the second was simple processing and the third was working memory. Simple processing is the ability to carry out simple instructions; complex processing is the ability to complicated tasks.

AD patients

Application of the eigenvalue-greater-than-1.0 rule suggested a five-factor solution. The first factor accounted for 38.3% of the variance, and the subsequent four factors for 12.0%, 6.9%, 5.4% and 4.2%, respectively.

The factor loadings of each item after varimax rotation are presented in Table 2. For the first factor, all items had positive loadings. This factor had large loadings with “registration”, “naming”, “repeat a sentence”, “three-step command” and “read and follow an instruction” tasks. The second factor had large loadings with “orientation to place” tasks, the “write a complete sentence” task and the “copies drawing of two polygons” task, the third with “orientation to time” tasks, the fourth with “delayed recall” tasks and the fifth with “serial sevens” tasks. However, the item “hospital” of “orientation to place” tasks appeared for not the second factor but the third, and “season” of “orientation to time” did not appear in five factors. The first factor corresponds to simple processing and the fifth corresponds to working memory. Items of complex processing were divided in the second, the third and the fourth factor.

Item response analysis

In the factor analysis, all items of the first factor had positive loadings, and the eigenvalue was much greater than the second factor for all participants and for AD patients. This showed the MMSE (Kitamura version) responses of these two groups had practical unidimensionality. We therefore carried out item response analysis to examine the ordering of items.

Characteristic curves of all participants

The characteristic curves (ogives) for all 28 items based on the MMSE (Kitamura version) responses of all

Table 1 Factor loadings after varimax rotation of the all patients

		Factor 1	Factor 2	Factor 3
1-1	What is the year?	0.809	0.250	0.309
1-2	What season of the year is it?	0.720	0.468	0.209
1-3	What is the day of the week?	0.794	0.293	0.292
1-4	What is the month?	0.803	0.355	0.259
1-5	What is the date?	0.748	0.236	0.297
2-1	What prefecture are we in?	0.695	0.464	0.229
2-2	What city or town are we in?	0.760	0.408	0.244
2-3	Which hospital are we in?	0.802	0.354	0.259
2-4	What floor of the building?	0.698	0.482	0.214
2-5	What district are we in?	0.733	0.350	0.303
3	Can repeat three words	0.360	0.825	0.130
4-1	First serial subtraction	0.624	0.521	0.276
4-2	Second serial subtraction	0.534	0.268	0.595
4-3	Third serial subtraction	0.399	0.175	0.812
4-4	Fourth serial subtraction	0.300	0.135	0.920
4-5	Fifth serial subtraction	0.278	0.119	0.833
5-1	Remembered three words (one word)	0.744	0.367	0.247
5-2	Remembered three words (two words)	0.680	0.351	0.268
5-3	Remembered three words (three words)	0.634	0.238	0.273
6-1	Can name a "watch"	0.343	0.817	0.132
6-2	Can name a "pencil"	0.313	0.821	0.127
7	Can repeat "Everyone pulls the rope together"	0.485	0.655	0.184
8-1	Takes paper in right hand	0.268	0.806	0.126
8-2	Folds paper in half	0.288	0.865	0.140
8-3	Put paper down on lap	0.246	0.866	0.136
9	Can read and follow instruction	0.507	0.667	0.161
10	Writes a complete sentence	0.622	0.573	0.201
11	Copies drawing of two polygons	0.647	0.502	0.234
	Eigenvalue	18.137	2.657	1.372
	Cumulative contribution ratio	0.648	0.743	0.792

Figures in bold show factor loadings > 0.4.

participants were drawn (Fig. 1). It appeared that the order of ascending ordering was: "naming", "three-step command", "registration", "repeat a sentence" and "read and follow an instruction", "write a complete sentence", "copies drawing of two polygons", "orientation to place", "delayed recall", "orientation to time" and "serial sevens" tasks. This order had a Rep of 0.952, PPR of 0.807 and PPR* of 0.810. When defining the cognitive impairment as less than 23 points of the MMSE, sensitivity and specificity for both "year" task and "day" task were more than 90% to detect the impairment ("year": sensitivity 92.5%, specificity 96.3%; "day": sensitivity 92.4%, specificity 91.7%).

To identify a more simplified and efficient scale, items with less unidimensionality or similarity were deleted, and ogives of the remaining 10 items were drawn (Fig. 2). These curves showed a Rep of 0.963, PPR of 0.842 and PPR* of 0.837. A correct answer rate of 50% was reached in the following order: "naming",

"three-step command", "registration", "repeat a sentence", "write a complete sentence", "copies drawing of two polygons", "orientation to place", "delayed recall", "orientation to time" and "serial sevens" tasks. The "read and follow an instruction" task was deleted, because the factor loading and the curve were similar to those for the "repeat a sentence" task.

Characteristic curves of AD patients

The ogives for all 28 items based on the MMSE (Kitamura version) reactions of the AD patients were drawn. It appeared that the order of ascending ordering was: "three-step command" and "naming", "registration", "repeat a sentence" and "read and follow an instruction", "write a complete sentence", "copies drawing of two polygons", "delayed recall", "orientation to place" and "serial sevens" tasks. This order had a Rep of 0.935, PPR of 0.706 and PPR* of 0.577.

Table 2 Factor loadings after varimax rotation of the Alzheimer's disease patients group

		Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
1-1	What is the year?	0.024	0.048	0.465	0.105	0.381
1-2	What season of the year is it?	0.297	0.386	0.268	0.285	0.079
1-3	What is the day of the week?	0.131	0.106	0.587	0.448	0.048
1-4	What is the month?	0.137	0.382	0.463	0.368	0.078
1-5	What is the date?	0.047	0.166	0.720	0.148	0.183
2-1	What prefecture are we in?	0.285	0.503	0.069	0.092	0.069
2-2	What city or town are we in?	0.224	0.418	0.386	0.128	0.038
2-3	Which hospital are we in?	0.126	0.287	0.625	0.296	0.159
2-4	What floor of the building?	0.302	0.470	0.367	0.283	-0.024
2-5	What district are we in?	0.112	0.490	0.284	-0.037	0.167
3	Can repeat three words	0.792	0.289	0.058	0.205	0.036
4-1	First serial subtraction	0.323	0.634	0.205	0.182	0.131
4-2	Second serial subtraction	0.107	0.450	0.040	0.122	0.405
4-3	Third serial subtraction	0.011	0.231	0.154	0.212	0.629
4-4	Fourth serial subtraction	0.030	0.030	0.194	0.044	0.954
4-5	Fifth serial subtraction	0.036	0.014	0.066	0.055	0.783
5-1	Remembered three words (one word)	0.201	0.182	0.270	0.757	0.126
5-2	Remembered three words (two words)	0.229	0.214	0.176	0.725	0.148
5-3	Remembered three words (three words)	0.114	0.141	0.206	0.594	0.116
6-1	Can name a "watch"	0.780	0.288	0.106	0.144	0.021
6-2	Can name a "pencil"	0.772	0.259	0.100	0.148	0.016
7	Can repeat "Everyone pulls the rope together"	0.576	0.497	0.100	0.214	0.050
8-1	Takes paper in right hand	0.784	0.208	0.040	0.067	0.053
8-2	Folds paper in half	0.901	0.169	0.116	0.079	0.041
8-3	Put paper down on lap	0.905	0.155	0.114	0.093	0.036
9	Can read and follow instruction	0.551	0.546	0.120	0.215	0.041
10	Writes a complete sentence	0.375	0.672	0.109	0.215	0.058
11	Copies drawing of two polygons	0.274	0.702	0.130	0.182	0.014
	Eigenvalue	10.717	3.348	1.930	1.518	1.164
	Cumulative contribution ratio	0.383	0.502	0.571	0.626	0.667

Figures in bold show factor loadings > 0.4.

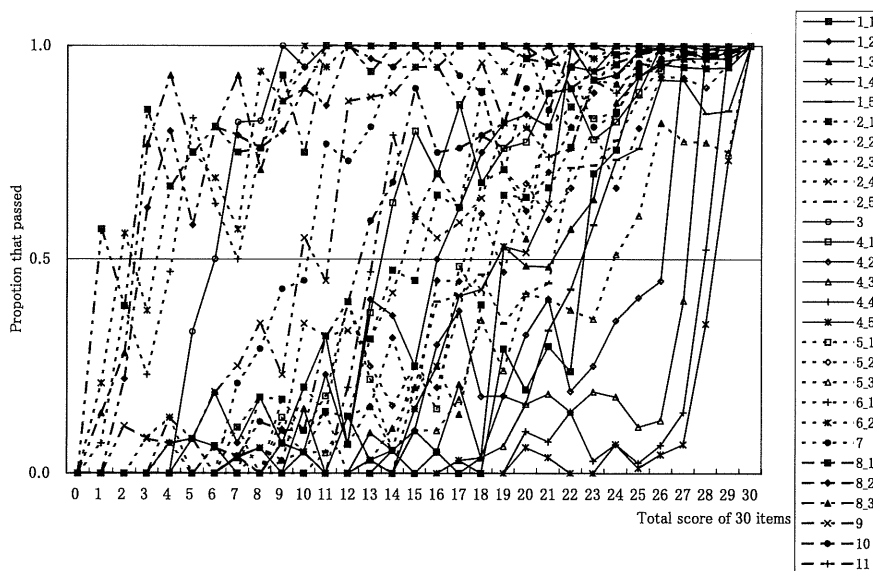


Figure 1 Ogives from all Mini-Mental State Examination items of all patients. It appeared that the order of ascending ordering was: "naming", "three-step command", "registration", "repeat a sentence" and "read and follow an instruction", "write a complete sentence", "copies drawing of two polygons", "orientation to place", "delayed recall", "orientation to time" and "serial sevens" tasks. This order had a reproducibility of 0.952, Jackson's plus percentage ratio of 0.807 and Nishisato's plus percentage ratio of 0.810.

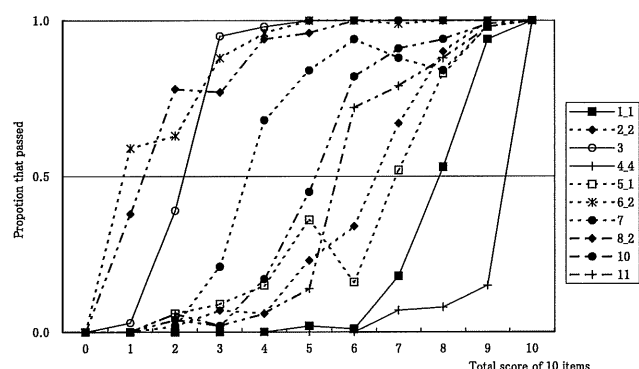


Figure 2 Ogives from 10 Mini-Mental State Examination items of all patients. To identify a more simplified and efficient scale, items with less unidimensionality or similarity were deleted, and ogives of the remaining 10 items were drawn. A correct answer rate of 50% was reached in the following order: “naming”, “three-step command”, “registration”, “repeat a sentence”, “write a complete sentence”, “copies drawing of two polygons”, “orientation to place”, “delayed recall”, “orientation to time” and “serial sevens” tasks. These curves showed a reproducibility of 0.963, Jackson’s plus percentage ratio of 0.842 and Nishisato’s plus percentage ratio of 0.837.

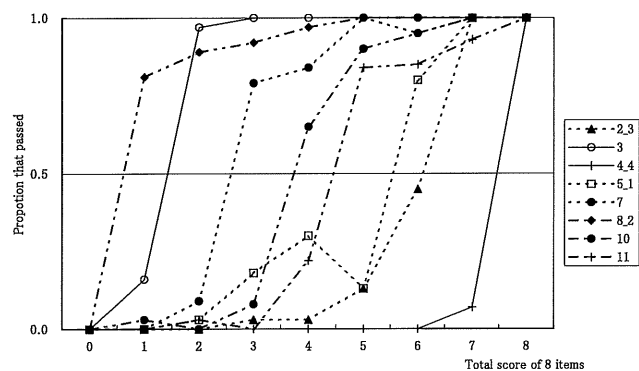


Figure 3 Ogives from eight Mini-Mental State Examination items of the Alzheimer’s disease patients group. To identify a more simplified and efficient scale, items with less unidimensionality or similarity were deleted, and ogives of the remaining eight items were drawn. A correct answer rate of 50% was reached in the following order: “three-step command”, “registration”, “repeat a sentence”, “write a complete sentence”, “copies drawing of two polygons”, “delayed recall”, “orientation to place” and “serial sevens” tasks. These curves showed reproducibility of 0.956, Jackson’s plus percentage ratio of 0.823 and Nishisato’s plus percentage ratio of 0.748.

To identify a more simplified and efficient scale, items with less unidimensionality or similarity were deleted, and ogives of the remaining eight items were drawn (Fig. 3). These curves showed Rep 0.956, PPR 0.823 and PPR*0.748. A correct answer rate of 50% was reached in the following order: “three-step command”, “registration”, “repeat a sentence”, “write a complete

sentence”, “copies drawing of two polygons”, “delayed recall”, “orientation to place” and “serial sevens” tasks. The “naming” and “read and follow an instruction” tasks were deleted, because the factor loadings and the curves were similar to those of the “three-step command” tasks and “repeat a sentence” task, respectively. The “orientation to time” tasks were also deleted, because the curves were similar to those of the “orientation to place” tasks.

Discussion

Factor analysis and item response analysis of the MMSE (Kitamura version) responses of all participants showed that the MMSE (Kitamura version) was practically a unidimensional scale in terms of level of difficulty. In addition, the present study showed multiple cognitive areas. A three-factor solution was suggested here; complex processing, that is “orientation” and “recall” as the first factor; simple processing, that is “registration” and “language” as the second; working memory, that is “attention and calculation” as the third; consistent with the five areas suggested by Folstein *et al.*¹

For the AD patients, the MMSE (Kitamura version) also had unidimensionality in terms of level of difficulty. This suggests the order of impairment in AD. Also, this might help differentiate AD from other mental illness. A five-factor solution was suggested in this group. Compared with the areas suggested by Folstein *et al.*,¹ the first factor comprised “registration” and “language” (with the exception of the “write a complete sentence” task and the “copies drawing of two polygons” task), the second factor was composed of “orientation to place” tasks (with the exception of “hospital”), the third of “orientation to time” tasks (with the exception of “season”), the fourth of the “recall” and the fifth of the “attention and calculation”. It therefore appears that the five areas described by Folstein *et al.*¹ had collapsed. As Yamanaka *et al.* pointed out, it is also possible that functional organization collapses in the cognitive style of AD patients and that these patients cannot link the knowledge or information necessary to solve the problems.¹³

According to the results for all participants, unidimensionality in the level of difficulty of items was confirmed. Thus, it can be said the MMSE (Kitamura version) is an orderly unidimensional assessment in Japanese older adults. The same can be said for Japanese nursing home residents with AD. Furthermore, the ordering among items was very similar between these two groups. This suggests that the widely used method of determining the presence of cognitive impairment according to a MMSE (Kitamura version) total score cut-off point is effective. In this context, the following possibilities were also suggested. First, for a patient with severe generalized cognitive disorder who cannot be tested with all MMSE (Kitamura version) items, the

cognitive function level can be estimated by testing with the easier items. Second, for a patient who cannot be tested with all MMSE (Kitamura version) items because of a physical disorder, such as “copies drawing of two polygons” task, cognitive function level can be estimated from the responses that he or she can be tested with. Third, because sensitivity and specificity for both “year” task and “day” task were more than 90%, cognitive impairment defined as less than 23 points of the MMSE (Kitamura version) can be predicted by a single question about orientation to time. These items are easily remembered and the correct answers readily available to the test user, therefore, the question about orientation to time might be useful in the screening assessment of cognition impairment.

The present study showed that some items of the Japanese MMSE (Kitamura version) could be deleted. This is desirable to construct a shorter, simpler version of the MMSE, which can be used as warranted by the clinical setting. Lou *et al.* analyzed the relationships among the MMSE items of 801 older Taiwanese patients and concluded that just 16 items were needed to describe the patient’s cognitive status.¹⁴ There are studies that used the Rasch model for item analysis and suggested a short form of MMSE.^{15,16} As Lou *et al.* showed, it is important to select all items that identify patients at risk and ensure detection of the onset of cognitive disturbance, and to decide on a cut-off point matched to these items.¹⁴ Further research is necessary in the Japanese version of the MMSE.

The present factor analysis of the MMSE (Kitamura version) in Japanese older adults and in Japanese nursing home residents with AD supports an inner structure of the multiple areas. However, the eigenvalue of the first factor was relatively large and loading of each item was positive. Item response analysis showed that the MMSE (Kitamura version) is a practically unidimensional scale in terms of order of difficulty. These findings show that the MMSE (Kitamura version) could be used as an essentially unidimensional measure of cognitive function. Item response analysis showed that the MMSE (Kitamura version) could be further simplified. Ten items for all participants and eight items for AD patients could be used as scales in a clinical setting. Because sensitivity and specificity for both “year” task and “day” task were more than 90%, the question about orientation to time might be useful in the screening assessment of cognition, instead of the total MMSE test (Kitamura version; cut-off point 23).

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Disclosure statement

None declared.

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