

# The “Test Your Memory” test performs better than the MMSE in a population without known cognitive dysfunction

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## ABSTRACT

**Aim:** To examine the relation of performance on the self-administered Test Your Memory test (TYM) and the Mini-Mental State Examination (MMSE) with a comprehensive neuropsychological assessment in a population sample including people with modest cognitive decrements.

**Methods:** Eighty-six participants (aged 56–77 years), without known cognitive dysfunction, performed a neuropsychological assessment including MMSE, and were asked to fill out the TYM. The relation between both the TYM and the MMSE and a neuropsychological assessment was examined by means of correlation analyses, area under the ROC curves for discriminating between a “normal” and “modest decrements” ( $\geq 1SD$  below the sample mean) group, and Bland–Altman plots.

**Results:** Correlation with the full neuropsychological assessment was significantly stronger for the TYM than the MMSE ( $r = 0.78$  versus  $r = 0.55$ ; Steiger's  $Z = 2.66$ ,  $p < 0.01$ ). The TYM showed an area under the ROC-curve of 0.88 (95% CI 0.80 to 0.97) for differentiating between “normal” and “modest decrements” compared with 0.71 (0.53 to 0.90) for the MMSE. Bland–Altman plots showed limits of agreement for the TYM of  $-1.10$  to  $1.10$  and for the MMSE of  $-1.39$  to  $1.38$ .

**Conclusions:** The TYM showed good correlation with a neuropsychological assessment, performed better in discriminating between variations of cognition and showed more agreement with a neuropsychological assessment than the MMSE.

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## 1. Introduction

Brief cognitive tests are increasingly implemented in both clinical and research settings. They are not only used for early recognition of cognitive deficits and dementia [1], but also for measuring differences in cognitive functioning between groups, for assessment of treatment effects and for the detection of cognitive decline over time. For these purposes such an instrument should not only discriminate between dementia and normal cognitive functioning, but should also be able to measure more subtle variations in cognitive functioning.

The most widely used brief cognitive screening test is the Mini-Mental State Examination (MMSE) [2]. A recent addition to the available instruments is the Test Your Memory (TYM) test [3]. This test is self-administered by patients, takes about five minutes to complete, and intends to measure a broad range of cognitive domains [3]. In a memory

clinic setting, the TYM showed good diagnostic value compared with the MMSE [4,5]. Therefore, the TYM is a potentially interesting instrument to use, particularly in settings where little time is available for the assessment of cognitive functioning. One of those settings could be the practice of a general practitioner. The range of subtle cognitive decrements in a primary care population, however, is different from patients at the memory clinic, with more people performing in the range of “normal” cognitive functioning. The present study aimed to examine the relation of the performance on the TYM and the MMSE with a comprehensive neuropsychological assessment in a population sample including people with modest cognitive decrements.

## 2. Methods

### 2.1. Study population

Participants took part in a cluster-randomized trial in primary care in patients with screen-detected type 2 diabetes that compared the effectiveness of an intensive treatment versus standard care on cardiovascular outcome (the ADDITION-Netherlands study) [6,7]. Cognition was assessed in an add-on project of the main study in a subgroup of

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participants with type 2 diabetes [8], in people with an impaired fasting glucose and in people with a normal glucose level. Participants were aged between 50 and 70 years and participants had been screened for type 2 diabetes. Participants with normal glucose levels were relatives of participants with diabetes. Exclusion criteria were previously diagnosed dementia, a known psychiatric or neurological disorder that could influence cognitive functioning, a history of alcohol or substance abuse or the inability to complete a neuropsychological assessment. Participants with a previous non-invalidating stroke could participate. During the neuropsychological examination participants were asked to fill out the TYM after they had completed a full neuropsychological assessment that also included the MMSE. The present study included all participants who completed the TYM ( $n = 86$ ). The ADDITION-study was approved by the medical ethics committee of the University Medical Center Utrecht, The Netherlands, and was completed in accordance with the Helsinki Declaration. Written informed consent was obtained from all participants.

## 2.2. Neuropsychological assessment

The neuropsychological assessment consisted of twelve verbal and nonverbal tasks addressing six cognitive domains. The division in cognitive domains was made a priori, according to standard neuropsychological practice and cognitive theory [9]. The domain 'abstract reasoning' was assessed by Raven Advanced Progressive Matrices. The domain "memory" was assessed by the subtest Digit Span of the Wechsler Adult Intelligence Scale –3rd edition (WAIS-III) [10], the Corsi Block-tapping Task [11], the Rey Auditory Verbal Learning Test [12], the Location Learning Test [13] and the delayed recall of the Rey-Osterrieth Complex Figure Test [14]. The domain "information-processing speed" was assessed by the Trail-making Test Part A [15], the Stroop Color-Word Test (part 1 and 2) [16] and the subtest Symbol Digit Substitution of the WAIS-III [10]. The domain "attention and executive function" was assessed by the Trail-making Test Part B (ratio score) [15], the Stroop Color-Word Test (part 3; ratio score) [16], the Brixton Spatial Anticipation Test [17], a letter fluency test using the letters "N" and "A" and category fluency (animal naming) [18]. The domain "visuoconstruction" was assessed by the copy trial of the Rey-Osterrieth Complex Figure Test. Finally, the domain "language comprehension" was assessed with the Token Test (short form) [19]. Subsequently the MMSE was administered. Educational level was recorded in seven categories [20] and subsequently translated into years of education [21]. The tests were administered in a fixed order at the patients' home by neuropsychologists and neuropsychologists in training. The entire battery took about 90 minutes to complete.

Raw test scores of the neuropsychological assessment were standardized into z-scores per test, based on the mean and the pooled standard deviation (SD) of the whole sample that was included in these analyses. The individual's z-score reflects the number of SDs a measurement deviates from the mean of this sample. The z-score of each domain was calculated by averaging all separate test z-scores comprising that domain. The cognitive domains in the neuropsychological assessment were determined a priori and theory-based, instead of with factor analysis. Previous studies by our group have shown that modest differences can be detected with these predefined domains [22,23]. We preferred this procedure above factor analysis on the data from the neuropsychological assessment. A composite score was also calculated by averaging the z-scores of the six domains, representing a "global cognition" score.

## 2.3. The Test Your Memory test

The TYM was developed to test a range of cognitive functions and consists of 10 subtasks [3]. It is a paper-and-pencil, self-administered

test and takes a person approximately five minutes to fill out. The tasks include orientation (10 points), ability to copy a sentence (2 points), semantic knowledge (3 points; assessed by the questions "who is the prime minister" and "in what year did the first world war start"), calculation (4 points), verbal fluency (4 points), similarities (4 points), naming (5 points), visuo-spatial abilities (2 tasks, total 7 points) and recall of a copied sentence (6 points). The ability to complete the test without help provides an 11th score (5 points). The maximum score is 50 points with lower scores indicating worse cognitive performance. The TYM was translated into Dutch after which a bilingual native English speaker back-translated the Dutch version into English, which resulted in a version almost identical to the original version.

## 2.4. Statistical analyses

Categorical variables are reported as numbers and percentages, continuous variables as means with SD and not normally distributed variables as median with interquartile range (IQR). Differences between groups in demographic variables and cognitive scores were analyzed with Chi-square tests for categorical variables, independent t-tests for normally distributed continuous variables and Mann-Whitney tests for not normally distributed continuous variables.

The relation between both the TYM and the MMSE and the neuropsychological assessment, which were administered consecutively, was examined in three steps. First, the correlations between both the TYM and the six domains of the neuropsychological assessment and between the MMSE and the six domains as well as the composite score of the neuropsychological assessment were examined using Spearman correlation coefficients, as the results from the TYM and the MMSE were not normally distributed. Differences between the correlations of the two brief cognitive tests with the neuropsychological assessment were statistically tested by means of the Steiger's Z-test [24]. In the primary analyses, no distinction was made between different categories of glucose regulation (diabetes, impaired fasting glucose, normal glucose level). However, because patients with type 2 diabetes were overrepresented in our sample and type 2 diabetes has been associated with modest cognitive decrements [25], a sensitivity analysis was performed adjusting the correlations for diabetes status.

Second, the sample was divided into two groups based on the scores of the neuropsychological assessment. Participants performing 1 SD or more below the mean of the whole sample on the composite z-score were defined as the group with "modest decrements"; those with a score above  $-1$  SD were defined as "normal cognition". This dichotomization translates into a "below average" performance (lowest 16%) of the total sample for the "modest decrements" group. Based on the discrimination of these two groups, a receiver operating characteristics (ROC) curve was plotted to assess the discriminative power of the TYM and the MMSE respectively.

Bland and Altman illustrated that a high correlation between two measures does not necessarily imply that they give an equally high or low estimation of true values [26]. Therefore, in the third step agreement between performance on the TYM, respectively the MMSE, and the neuropsychological assessment was examined with Bland-Altman plots. The mean of the measurements (x-axis) was plotted against the difference between the two measurements (y-axis); both expressed as standardized z-scores with the accompanying corrected 95% limits of agreement [26]. These plots quantify the difference between performances on the TYM and the MMSE on the one hand and the neuropsychological assessment on the other. They create an interval in which 95% of the differences between the two instruments are expected to lie. A narrow 95% interval indicates greater agreement between the tests.

**Table 1**  
Raw neuropsychological test scores of the total sample.

Domain	Test	Mean $\pm$ SD	Total range
Global	TYM-score	44.1 $\pm$ 4.6	24–48
	MMSE-score	28.8 $\pm$ 1.3	22–30
Memory	WAIS-III Digit Span forward <sup>b</sup>	49.5 $\pm$ 21.3	20–108
	WAIS-III Digit Span backward <sup>b</sup>	28.8 $\pm$ 18.8	9–96
	Corsi Block-Tapping Test forward <sup>b</sup>	41.5 $\pm$ 13.3	12–77
	Corsi Block-Tapping Test backward <sup>b</sup>	42.3 $\pm$ 13.7	12–96
	RAVLT total trials 1–5	44.0 $\pm$ 10.7	20–67
	RAVLT delayed recall	8.9 $\pm$ 3.3	2–15
	RAVLT recognition	28.6 $\pm$ 2.1	21–30
	LLT total trails 1–5 <sup>a</sup>	22.8 $\pm$ 18.9	0–86
	LLT learning index	0.6 $\pm$ 0.3	0.1–1
	LLT delayed trial <sup>a</sup>	1.9 $\pm$ 3.5	0–14
Information-processing speed	Complex Figure Test – Delay	17.7 $\pm$ 6.4	5–33
	Stroop Color Word Test I <sup>a</sup>	49.8 $\pm$ 10.6	32–87
	Stroop Color Word Test II <sup>a</sup>	62.7 $\pm$ 12.2	43–112
	TMT Part A	42.0 $\pm$ 17.2	16–107
	WAIS-III Digit Symbol	62.1 $\pm$ 16.9	20–98
Attention and executive functioning	Stroop Color Word Test III <sup>a</sup>	108.3 $\pm$ 28.9	64–220
	TMT Part B	88.1 $\pm$ 42.8	37–272
	Letter fluency (mean of N + A)	12.3 $\pm$ 4.4	4–26
	Category fluency (animals)	32.2 $\pm$ 8.9	9–53
	Brixton Spatial Anticipation Test <sup>a</sup>	16.1 $\pm$ 4.6	5–31
Abstract reasoning	Raven APM	7.7 $\pm$ 2.4	1–12
Visuoconstruction	Complex Figure Test – Copy	33.5 $\pm$ 2.9	20–36
Language comprehension	Token test	19.0 $\pm$ 2.2	12–21

RAVLT, Rey Auditory Verbal Learning Test; LLT, Location Learning Test; TMT, Trail Making Test; WAIS-III, Wechsler Adult Intelligence Scale – Third edition; Raven APM, Raven Advanced Progressive Matrices.

<sup>a</sup> Higher test scores reflect worse performance.

<sup>b</sup> Product score: span length  $\times$  number of correct items.

### 3. Results

#### 3.1. Study population

The TYM was completed by 86 persons of whom 46 were known with type 2 diabetes, 11 were diagnosed with impaired fasting glucose and 29 had a normal fasting glucose. Eighty-one participants also completed the MMSE. Due to time constraints five participants were not able to complete a MMSE. The mean age of participants was  $65.8 \pm 5.4$  years, 59% was male and the average years of education was  $11 \pm 3$  years. No differences were found for age and sex between participants with type 2 diabetes and impaired fasting or normal glucose. Patients with diabetes had less years of education. Table 1 shows the raw neuropsychological test scores for the total sample. The TYM and the MMSE scores were not normally distributed (Kolmogorov-Smirnov: TYM  $z = 0.21$ ,  $p < 0.001$ ; MMSE  $z = 0.16$ ,  $p < 0.001$ ). The total sample had a median TYM-score of 44 (IQR 42–48) and a MMSE-score of 29 (IQR 28–30). None of the patients had a MMSE-score below 22 points or showed signs of dementia on the neuropsychological assessment.

**Table 2**  
Correlations of TYM and MMSE with neuropsychological assessment within the total sample.

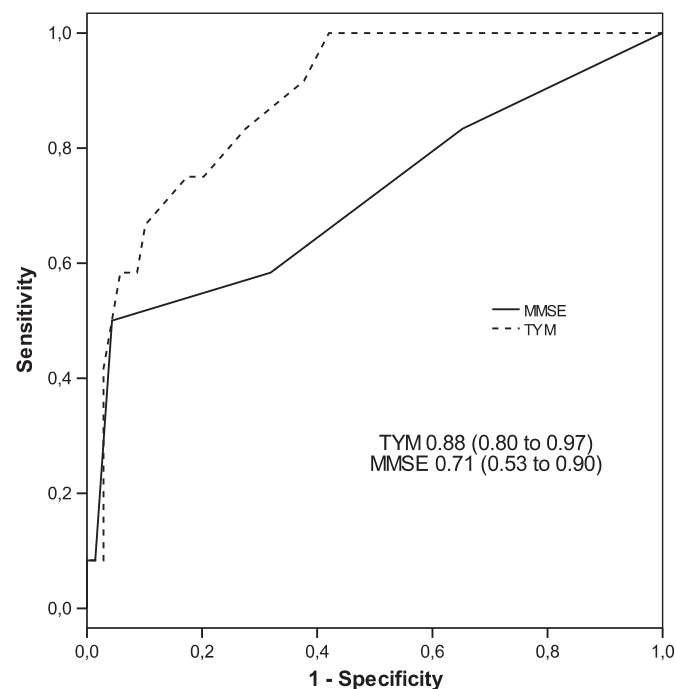
	TYM		MMSE	
	<i>r</i>	<i>p</i> -Value	<i>r</i>	<i>p</i> -Value
Composite	0.78	<0.001	0.55	<0.001
Memory	0.44	<0.001	0.38	<0.001
Information-processing speed	0.66	<0.001	0.38	0.001
Attention and executive function	0.61	<0.001	0.37	0.001
Abstract reasoning	0.54	<0.001	0.42	<0.001
Visuoconstruction	0.44	0.001	0.27	0.02
Language comprehension	0.67	<0.001	0.52	<0.001
MMSE	0.49	<0.001	–	–

TYM: Test Your Memory test; MMSE: Mini-Mental State Examination.

*r* = Spearman correlation coefficient.

#### 3.2. Correlations with a neuropsychological assessment

The correlation coefficients of the TYM and the MMSE with the full neuropsychological assessment and the individual domains are presented in Table 2. The TYM showed a strong correlation with the full neuropsychological assessment ( $r = 0.78$ ;  $p < 0.001$ ). Correlations with the individual domains ranged from 0.44 to 0.67, all were statistically significant, with the strongest correlation for language

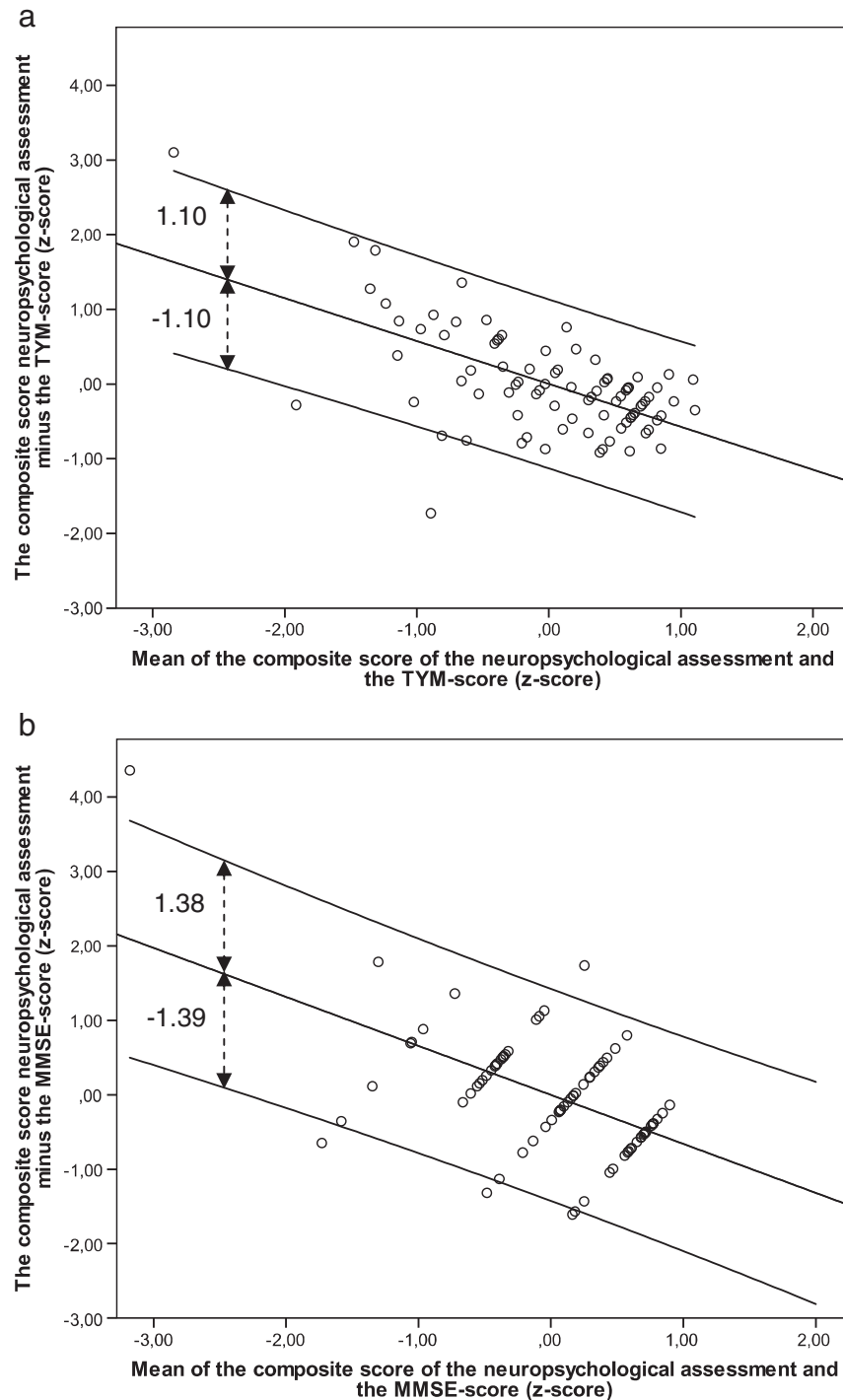


**Fig. 1.** Receiver operating characteristic curve for TYM (dotted line) and MMSE (solid line) differentiating between normal cognition and modest decrements.

comprehension and the weakest for memory and visuoconstruction. The relation between the MMSE and the full neuropsychological assessment was weaker in all separate domains, ranging from 0.27 to 0.52, with the strongest correlation for language comprehension and the weakest for visuoconstruction. In a direct comparison, the TYM showed a statistically significant stronger correlation with the full neuropsychological assessment than the MMSE (Steiger's  $Z = 2.66$ ;  $p = 0.008$ ). The sensitivity analyses with adjustment for type 2 diabetes yielded similar correlation coefficients (data not shown).

### 3.3. Discriminative values of TYM and MMSE

The participants were divided in two groups to assess the discriminative values of the tests for detecting mild cognitive decrements. Compared to the “normal cognition” group ( $n = 73$ ) participants in the “moderate decrements” group ( $n = 13$ ) were older ( $65.1 \pm 5.4$  versus  $69.8 \pm 3.9$ ;  $p = 0.001$ ) and more often male (54.8% versus 84.6%;  $p = 0.04$ ). Both the TYM and the MMSE score were significantly lower in the “modest decrements” group: TYM 38 (36–43) versus 46 (43–48),  $p < 0.001$ ; MMSE 28 (27–29) versus 29 (28–30),



**Fig. 2.** Bland–Altman plots comparing TYM (a) and MMSE (b) with a neuropsychological assessment. Differences (y-axis; neuropsychological assessment minus TYM/MMSE) are plotted against means of the neuropsychological assessment and the TYM/MMSE (x-axis). All data are expressed as standardized z-scores.



$p = 0.01$ . The area under the ROC curve was higher for the TYM with 0.88 (95%-CI 0.80 to 0.97) compared with 0.71 (95%-CI 0.53 to 0.90) for the MMSE (Fig. 1).

### 3.4. Agreement of TYM and MMSE with a neuropsychological assessment

Fig. 2 shows Bland–Altman plots comparing agreement between the TYM and the MMSE respectively and the full neuropsychological assessment, with accompanying 95% limits of agreement. The plots show limits of agreement for the TYM of  $-1.10$  to  $1.10$  and for the MMSE of  $-1.39$  to  $1.38$ , indicating that the agreement of the TYM with the neuropsychological assessment was higher than between the MMSE and the full assessment. The plot of the TYM shows a negative relation between the TYM and the neuropsychological assessment indicating that the TYM tends to slightly underestimate the performance at lower cognitive functioning (upper left quadrant) and slightly overestimate performance at better cognitive functioning (lower right quadrant).

## 4. Discussion

The present study provides a detailed examination of the relation between a comprehensive neuropsychological assessment and the TYM in a population of people without dementia and compared this to the MMSE. The results showed that the TYM test had a stronger correlation with a full neuropsychological assessment and its separate cognitive domains than the MMSE. In addition, the TYM had more discriminative power to distinguish people with modest decrements from normal cognitive functioning. Analysis of agreement indicated better agreement between the TYM and the neuropsychological assessment as compared with the MMSE.

After the index-study by Brown et al., who determined the accuracy of the TYM for discriminating patients with Alzheimer's disease from controls in a memory clinic setting [3], two other studies also examined its diagnostic utility in a memory clinic population [4,5]. All found good diagnostic properties for the TYM, with two out of three finding superior values compared to the MMSE [3,5]. Brown et al. presented normal scores for the TYM of 47 and 46 points for respectively people aged between 18 to 70 and 70 to 80 years and a cut off score of  $\leq 42$  points for Alzheimer's disease [3]. Hancock et al. revised the optimal cut off score to  $\leq 30$  points to obtain increased accuracy for the detection of dementia [4]. Since the present study was performed in a population without dementia the cut offs that were previously established for the detection of early dementia could not be validated in our sample. Importantly, however, our primary aim was to compare the TYM to the MMSE in measuring variation in cognitive functioning in non-demented people, rather than validation of the cut off scores for the detection of dementia. In many studies the MMSE is used to give a global measure of cognitive functioning when examining the relation between risk factors and cognition or investigating the effects of treatment on cognition [27–29]. A meta-analysis, examining the performance of the MMSE, found that the MMSE has limitation when used for this purpose [30]. In this meta-analysis the MMSE distinguished only 63% of the people with mild cognitive impairment (MCI) from healthy subjects indicating that the MMSE is insufficient measuring relatively small decline in cognition. To examine whether the TYM could discriminate between small decrements within the normal cognitive spectrum, we divided the sample into two groups. People performing in the lowest 16% of the study population were categorized as those with modest decrements. The cut-off value, namely one SD, was to some extent arbitrary and based on the sufficient number of people in the modest decrements group to allow the analyses. Nevertheless, the areas under the ROC curve did not change significantly with other cut off points (data not shown). Our results suggest that the TYM is a good alternative for examining global cognitive performance as it is more

sensitive to mild decrements and it shows higher correlation and agreement with a neuropsychological assessment. The performance of the MMSE in measuring variation in normal cognitive functioning has not been previously examined. The still relatively wide limits of agreement of the Bland–Altman plots however showed that these tests cannot simply replace a comprehensive neuropsychological assessment.

The present study used a comprehensive neuropsychological assessment in a relatively healthy population aged between 56 and 77 years. Hence, the performance of the TYM was assessed in a population with at most mild cognitive decrements. Whether the TYM has similar qualities in a population that also includes patients with more severe cognitive impairment requires further examination. Another limitation might be the overrepresentation of patients with diabetes. However, by including this group of patients with more variation in cognitive functioning, we increased the contrast in the performance range in both the neuropsychological assessment and the screening instruments leading to valuable insight in the relation between the instruments and a neuropsychological assessment. Moreover, sensitivity analyses indicate that the high proportion of individuals with diabetes did not influence our results.

In conclusion, the TYM showed good correlation with a comprehensive neuropsychological assessment in people without clinically relevant cognitive decrements. The TYM had more discriminative power in discriminating between variations of cognition and showed more agreement with a neuropsychological assessment than the MMSE.

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## Conflict of interest

The authors report no conflict of interest.

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