

Development of a Web-Based Application for Cognitive and Functional Assessment in Dementia Screening

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Abstract

Methods: We developed a web-based application—the Healthy Brain Test—that allows patients or family members to complete cognitive and functional assessments at home. The battery includes electronic versions of the Thai Mental State Examination (e-TMSE), a clock drawing test, and a category verbal fluency test. It also includes digital versions of the short form of the Informant Questionnaire on Cognitive Decline in the Elderly (IQCODE-16) and cognitive instrumental activities of daily living (IADLs). We computed correlations; generated receiver operating characteristic curves; and estimated sensitivity and specificity using PASW Statistics version 18 (SPSS Inc, Chicago, IL, USA).

Results: We enrolled 198 participants (69% female; median age 69.4 years), and 57.1% had more than 6 years of formal education. Forty-four participants had major neurocognitive disorder, 58 had mild neurocognitive disorder, and 96 were normal controls. The e-TMSE correlated strongly with the paper-and-pencil Thai Mental State Examination ($r = 0.837$, $p < 0.001$). Category verbal fluency, IQCODE-16, and cognitive IADLs showed similarly significant correlations ($p < 0.0001$). For e-TMSE, the area under the curve was 0.84 (bootstrapped 95% CI 0.78–0.89); a cutoff of ≥ 23 yielded 88.64% sensitivity and 70.13% specificity for diagnosing major neurocognitive disorder.

Conclusion: The e-TMSE, clock drawing, verbal fluency, IQCODE-16, and IADL assessments correlated significantly with established cognitive tests. The Healthy Brain Test web-based tool provides a practical, accessible option for early detection of cognitive impairment in clinical and community settings. Further research is needed to confirm effectiveness in broader, unsupervised populations.

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Original Manuscript

Development of a Web-Based Application for Cognitive and Functional Assessment in Dementia Screening

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Keywords:

Alzheimer's disease; Cognitive screening; Dementia; Functional assessment; Neurocognitive disorders; Neuropsychology; Web application

Abstract

Introduction: Dementia is common in older adults; therefore, screening is important for clinical care and epidemiological surveillance. In Thailand, web-based cognitive assessment tools remain underdeveloped despite their potential for widespread implementation. This study aimed to develop a digital instrument to evaluate cognitive and functional abilities and to explore optimal cutoff scores for identifying cognitive impairment.

Methods: We developed a web-based application—the *Healthy Brain Test*—that allows patients or family members to complete cognitive and functional assessments at home. The battery includes electronic versions of the Thai Mental State Examination (e-TMSE), a clock drawing test, and a category verbal fluency test. It also includes digital versions of the short form of the Informant Questionnaire on Cognitive Decline in the Elderly (IQCODE-16) and cognitive instrumental activities of daily living (IADLs). We computed correlations; generated receiver operating characteristic curves; and estimated sensitivity and specificity using PASW Statistics version 18 (SPSS Inc, Chicago, IL, USA).

Results: We enrolled 198 participants (69% female; median age 69.4 years), and 57.1% had more than 6 years of formal education. Forty-four participants had major neurocognitive disorder, 58 had mild neurocognitive disorder, and 96 were normal controls. The e-TMSE correlated strongly with the paper-and-pencil Thai Mental State Examination ($r = 0.837$, $p < 0.001$). Category verbal fluency, IQCODE-16, and cognitive IADLs showed similarly significant correlations ($p < 0.0001$). For e-TMSE, the area under the curve was 0.84 (bootstrapped 95% CI 0.78–0.89); a cutoff of ≤ 23 yielded 88.64% sensitivity and 70.13% specificity for diagnosing major neurocognitive disorder.

Conclusion: The e-TMSE, clock drawing, verbal fluency, IQCODE-16, and IADL assessments correlated significantly with established cognitive tests. The *Healthy Brain Test* web-based tool provides a practical, accessible option for early detection of cognitive impairment in clinical and community settings. Further research is needed to confirm effectiveness in broader, unsupervised populations.

Introduction

Cognitive performance often declines with normal healthy aging [1], with measurable deficits in episodic memory, working memory, verbal fluency, and executive control processes such as visual attention and set-shifting [2]. These age-related changes do not inevitably progress to dementia. However, dementia remains a significant public health challenge in Thailand, and prevalence rises sharply with age. A national survey reported that 3.3% of Thai adults aged 60 and over have some form of dementia, increasing from 1% at ages 60–64 to 31.3% among those aged 90 and above [3].

Digital technologies have advanced cognitive screening, offering potential benefits for clinical treatment, therapeutic interventions, and behavioral research. Web-based applications now extend beyond screening to support self-management, caregiver education, cognitive rehabilitation, and remote clinical monitoring. Recent studies indicate that such applications can contribute across the dementia care continuum [4–8].

In Thailand, web-based dementia care applications are still early in development. *Dementia U-Care*, designed to help community health workers screen and monitor cognitive data, has demonstrated feasibility and positive user experiences [9]. Sirirat et al. [10] introduced smartphone-based screening tools using the Thai version of the Mini-Mental State Examination (*MMSE-Thai 2002*) with text-to-speech and audio recording. More recently, Weerasak et al. [11] validated the Application-Based Cognitive Screening Test (*ACST*) for older Thai adults, reporting 92.9% sensitivity and 70% specificity.

Standard neuropsychological instruments, including the Mini-Mental State Examination and the Montreal Cognitive Assessment, have long served as benchmarks for detecting early cognitive impairment. The Mini-Mental State Examination shows sensitivity of 87%–97% and specificity of 70%–82%, depending on the population and selected cutoff points [12]. The Montreal Cognitive Assessment, designed to be more sensitive to mild cognitive impairment, typically achieves about 90% sensitivity and approximately 87% specificity [13]. Given population aging and demand for accessible screening, there is a need to develop localized, culturally appropriate digital tools. Therefore, we designed the *Healthy Brain Test*, a test battery usable via a web-based application on tablet computers and mobile phones. Our objectives were to develop a web-based cognitive and functional assessment platform aimed at dementia screening in older Thai adults and to design diverse cognitive modules targeting different cognitive domains. We also sought to evaluate correlations between the web-based assessments and traditional tools.

Methods

Study Population

Participants aged over 40 years were prospectively and purposefully recruited from the Faculty of Medicine Siriraj Hospital, Mahidol University, Bangkok, Thailand. Recruitment aimed to evaluate cognitive and functional performance for dementia screening using a dedicated web-based application. All participants had either relatives or long-term caregivers who could provide relevant information on cognitive status and daily functioning at present and over the past 10 years.

Inclusion and Exclusion Criteria

The inclusion criteria were provision of informed consent after full explanation of study objectives and procedures; adequate literacy, vision, and hearing; and ability to read and comprehend Thai. The exclusion criteria were acute confusion; impaired decision-making capacity due to cognitive or medical conditions; and severe physical or psychiatric illness.

Diagnostic Classification

The diagnoses of major and mild neurocognitive disorders were established according to the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition criteria [13]. Cognitively healthy controls were recruited from relatives or spouses of patients and community volunteers. These individuals had no reported cognitive decline, demonstrated normal performance on cognitive assessments, and maintained independence in daily functioning.

Ethical Considerations

All participants provided written informed consent before enrollment. The study protocol was approved by the Human Research Protection Unit, Faculty of Medicine Siriraj Hospital, Mahidol University, and conducted in accordance with the Declaration of Helsinki.

Study Design

This study employed a user-centered design approach to develop and validate a web-based cognitive and functional screening application for the early detection of dementia. Development proceeded through three consecutive phases involving collaboration among computer scientists, health informaticians, psychologists, and neurologists. All phases were guided by clinical relevance, usability, and data security considerations.

Phase I: Prototype Development and Usability Testing

In Phase I, we developed a prototype of the *Healthy Brain Test* web-based application and iteratively refined it to optimize usability. The application was designed for Android-based systems to ensure widespread accessibility and compatibility with mobile devices commonly used in community and clinical settings. Usability testing sessions with volunteer participants generated feedback that informed successive iterations of the user interface. The interface comprised two sections. The homepage introduced the application, provided general usage instructions, and presented an electronic informed consent form. Users were required to review and agree to the consent before accessing the assessment modules. The assessment section included five digital cognitive and functional tasks adapted from established neuropsychological assessments. Each task was preceded by a brief, standardized instructional message, and the design enhanced interactivity while reducing reliance on motor skills. Initial trials were conducted with volunteer participants to ensure content comprehension, ease of use, and engagement.

Phase II: The Pivot Study

A pilot study at Siriraj Hospital, Thailand, evaluated the validity of the *Healthy Brain Test* web-based cognitive screening application against traditional paper-and-pencil assessments. A total of 77 participants were enrolled (50 females and 27 males). Participants were categorized into three groups: 21 with major neurocognitive disorder (mild to moderate dementia), 23 with mild cognitive impairment, and 33 cognitively normal controls. Each participant completed both conventional and digital cognitive assessments. The traditional paper-and-pencil assessments included the standard Thai Mental State Examination (TMSE) and the clock drawing test (CDT), administered under the supervision of trained clinicians. After the paper-and-pencil tests, participants were guided through the web-based *Healthy Brain Test* application. The full assessment session lasted approximately 1–2 hours, depending on participant performance.

Phase III: Practical Use and Data Collection

In the final phase, we implemented the *Healthy Brain Test* web-based application in real-world settings across five health centers in Thailand. The sites were Siriraj Hospital, Vajira Hospital, Phatthalung Hospital, Phitsanulok Health Center 2, and Nakhon Phanom Hospital. This phase aimed to assess practical use in community-based and clinical environments and to facilitate the early detection of cognitive impairment and dementia. The application was accessible through healthcare professionals or via self-assessment under observation, and participants could complete the digital screening autonomously or with minimal assistance. This approach supported broader reach and feasibility across diverse settings, including rural areas. We enrolled 198 participants (137 females and 61 males). Based on clinical evaluation, participants were categorized as 44 with major neurocognitive disorder, 58 with mild cognitive impairment, and 96 cognitively normal controls. Digital screening assessed cognitive and functional performance using five standardized tasks embedded in the application. We also collected demographic and educational data and stored them on secure cloud servers, ensuring confidentiality and compliance with data protection standards.

The Healthy Brain Test Web-Based Application

The *Healthy Brain Test* is a web-based digital cognitive and functional screening tool that integrates five core neuropsychological tasks digitally adapted from validated conventional tests widely used to assess cognitive function. The battery included five tasks: a slightly modified electronic Thai Mental State Examination (e-TMSE); the CDT implemented as the Clox test; and a category verbal fluency test (VFT). The remaining tasks were the short form of the Informant Questionnaire on Cognitive Decline in the Elderly (IQCODE-16) and cognitive instrumental activities of daily living (cognitive IADLs). Illustrative screenshots of the assessment modules are shown in **Figure 1**.

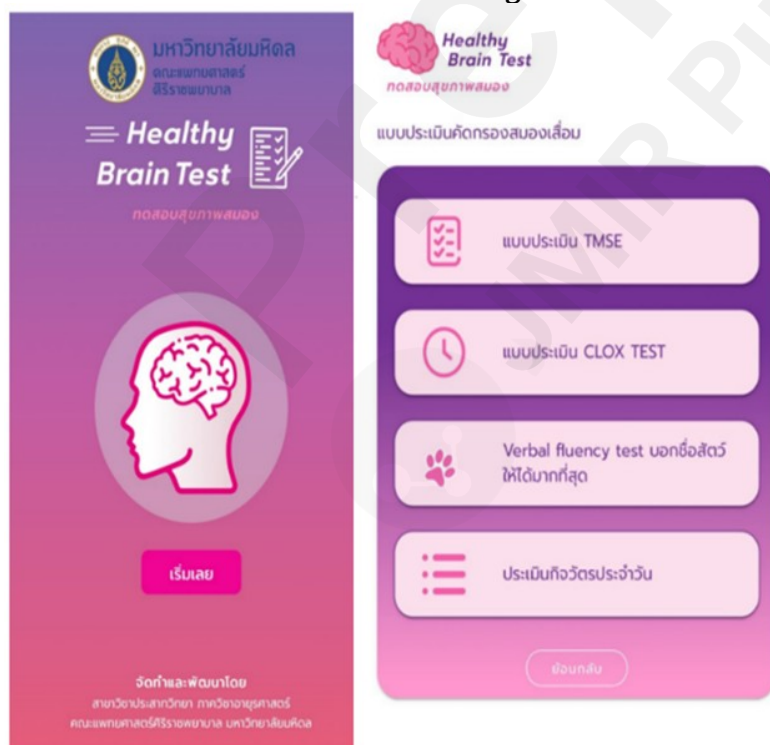


Fig. 1. Healthy Brain Test: module overview.

Screens illustrate five modules: electronic Thai Mental State Examination (e-TMSE), the Clox test (digitized clock drawing), category verbal fluency test (animal naming), IQCODE-

16, and cognitive instrumental activities of daily living (cognitive IADLs). No identifying information is displayed.

e-TMSE

The e-TMSE, a digital adaptation of the standard paper-and-pencil TMSE [15], was designed to assess cognitive function through an interactive web-based interface. The traditional TMSE consists of 11 items covering six cognitive domains: orientation, registration, attention and calculation, recall, language, and visuospatial abilities. Each component was implemented in the digital platform, and the original maximum total score of 30 points was preserved. Participants used touch to choose from on-screen options or to handwrite responses for language items. Samples of the e-TMSE test screens are shown in **Figure 2**.

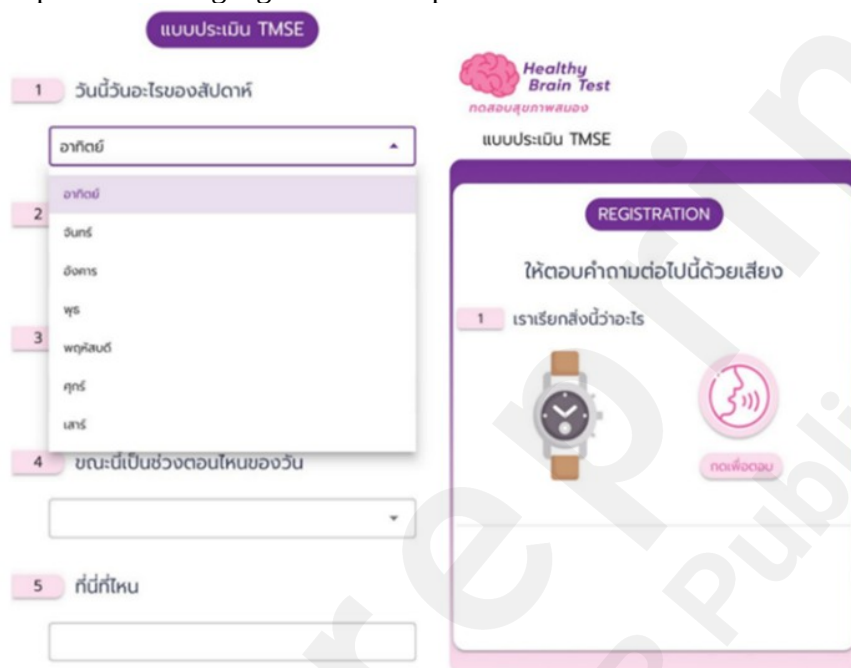


Fig. 2A. e-TMSE sample screens: orientation and registration.

The e-TMSE preserves TMSE structure and scoring (maximum total 30 points). The items shown—orientation and registration—use touch-based entry.

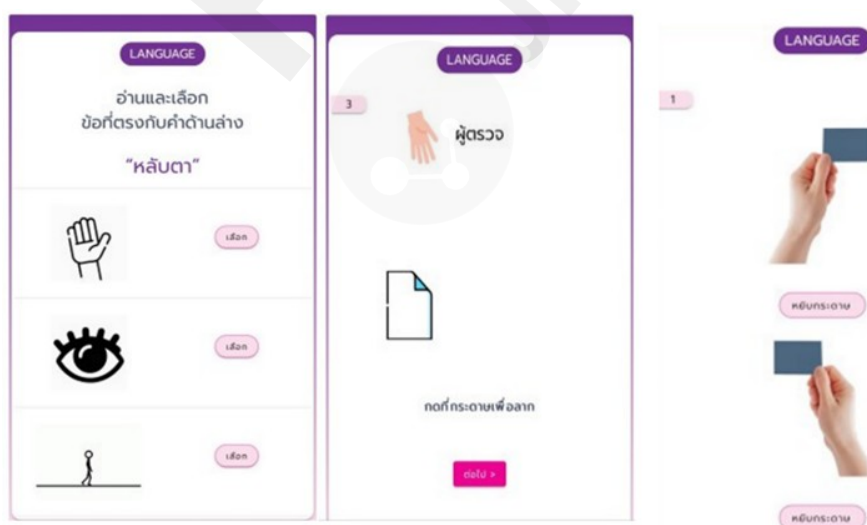


Fig. 2B. e-TMSE sample screens: language.

Language items allow on-screen handwriting and choice selection. Scoring follows the original TMSE rubric.

CDT

The CDT is widely used to assess visuospatial ability and executive function and has attracted interest for early cognitive impairment screening [16]. In this study, a digitized CDT variant, the Clox test, was implemented within the *Healthy Brain Test* application.

Participants drew a clock showing a specified time on a touch-based interface. The test used a 10-point scale, where 0 indicates severe impairment and 10 represents normal performance. Illustrative screenshots are shown in **Figure 3**.

Category VFT

The category (semantic) VFT is a well-established neuropsychological measure that assesses executive function and semantic memory and shows high sensitivity for detecting cognitive impairment, including mild cognitive impairment and dementia [17, 18]. In this task, participants generate as many words as possible from a specified category within a limited time, typically 1 minute. In the present study, we used the animal naming category and instructed participants to name as many animals as possible within 1 minute. Illustrative screenshots are shown in **Figure 4**.

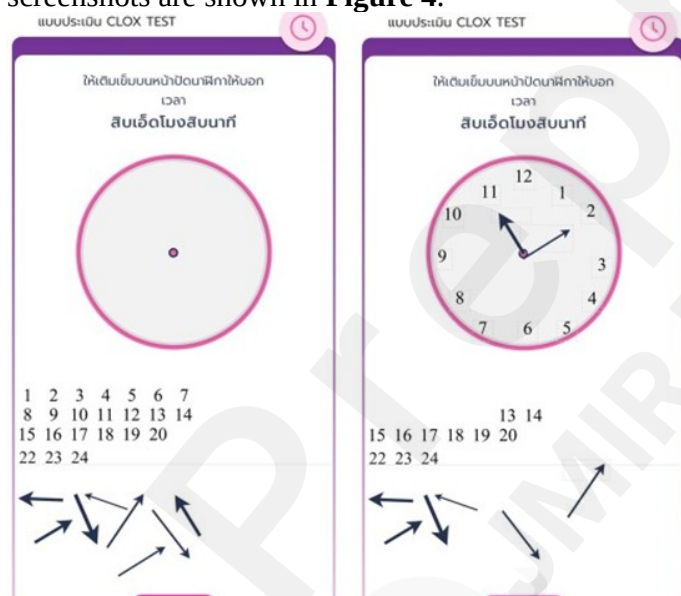


Fig. 3. Digitized clock drawing (the Clox test): sample screens.

Participants draw a clock showing a specified time on a touch-based canvas. Performance is scored on a 10-point scale (0 = greatest impairment; 10 = normal).



Fig. 4. Category verbal fluency test (animal naming): sample screens. Participants name as many animals as possible in 1 minute. The interface provides standardized instructions and timed entry.

IQCODE-16

The short form of the IQCODE consists of 16 items that assess informants' perceptions of a participant's cognitive decline by comparing current performance with performance 10 years earlier. In this study, informants were relatives, long-term paid caregivers, or neighbors who had been providing some care. They rated change on a 5-point scale from 1 (much improved) to 5 (much worse), and the score was the mean of the 16 items [19].

Cognitive IADLs

The cognitive IADL module in the *Healthy Brain Test* is derived from the validated Thai Activities of Daily Living (ADL) scale [20]. The instrument includes six basic ADL items and seven cognitive IADL items, and it evaluates the capacity to perform essential daily tasks that require physical function and cognitive integration. The Thai ADL measure has shown strong psychometric properties, including high test-retest reliability and robust construct validity. It also shows strong correlations with the TMSE, the Clinical Dementia Rating, the Barthel Index, and the Functional Activities Questionnaire.

Measurement

Baseline Assessment

Trained physicians and neurologists conducted structured interviews to obtain baseline clinical and demographic data, including age, sex, educational attainment, and cognitive status.

Statistical Analysis

We calculated the required sample size using an estimated dementia prevalence of 20% in

older Thai adults based on national guidelines [21]. With 95% confidence and a 5 % margin of error, we applied the standard prevalence formula:

$$n = \frac{Z^2 \times P \times (1 - P)}{d^2}$$

where n is the required sample size, Z is the 95% confidence Z-score (1.96), P is the expected prevalence (0.20), and d is the margin of error (0.05). This yielded a minimum sample size of 246 (5% margin of error) participants.

We analyzed data using PASW Statistics version 18 (SPSS Inc, Chicago, IL, USA).

Descriptive statistics summarized baseline demographic and clinical characteristics. To assess validity, we computed Spearman's correlation coefficients between digital test scores and conventional paper-and-pencil scores (TMSE and the CDT) because the data were not normally distributed. We considered $p < 0.05$ statistically significant. We also conducted receiver operating characteristic (ROC) curve analyses to evaluate the application's ability to distinguish cognitively impaired individuals from cognitively normal controls. We calculated the area under the curve (AUC) for each digital test domain to quantify overall diagnostic performance.

Results

Phase II: Participant Demographics and Initial Validation

This phase evaluated concordance and diagnostic accuracy between traditional paper-and-pencil assessments and web-based application tests. A total of 77 participants were categorized into three groups: dementia ($n = 21$), mild cognitive impairment ($n = 23$), and cognitively normal controls ($n = 33$). The dementia group had a significantly higher mean age than the other groups ($p = 0.003$). All cognitive and functional measures differed significantly between groups ($p < 0.001$). The dementia group showed the lowest performance on paper-and-pencil and web-based TMSE, clock drawing, and verbal fluency, and the highest ADL, cognitive IADLs, and IQCODE-16 scores, indicating greater functional impairment and cognitive decline. Demographic characteristics for all 77 participants are shown in **Table 1**.

Table 1. Participant demographics and clinical characteristics, initial phase (n = 77)

Variable	Dementia (n = 21)	MCI (n = 23)	Normal cognition (n = 33)	Total (n = 77)	p value
Age (years)	73.0 (69.5–79.0)	69.0 (63.0–75.0)	66.0 (56.5–72.0)	69.0 (63.0–75.0)	0.003
Female, n (%)	14 (66.7%)	15 (65.2%)	22 (66.7%)	51 (66.2%)	0.992
Formal education, n (%)					
- Primary	13 (61.9%)	6 (26.1%)	5 (15.2%)	24 (31.2%)	
- Secondary	1 (4.8%)	4 (17.4%)	4 (12.1%)	9 (11.7%)	
- Vocational	3 (14.3%)	3 (13.0%)	5 (15.2%)	11 (14.3%)	
- Bachelor's degree	3 (14.3%)	8 (34.8%)	15 (45.5%)	26 (33.8%)	
- Postgraduate	1 (4.8%)	2 (8.7%)	4 (12.1%)	7 (9.1%)	
e-TMSE	21.0 (16.5–23.0)	25.0 (24.0–28.0)	28.0 (25.5–29.0)	25.0 (23.0–28.0)	< 0.001
Clox test	7.0 (1.5–8.0)	10.0 (9.0–10.0)	10.0 (9.5–10.0)	10.0 (7.0–10.0)	< 0.001
Verbal fluency test	11.11 ± 4.99	17.61 ± 6.80	19.12 ± 4.61	16.48 ± 6.35	< 0.001
Basic ADLs	7.0 (3.5–9.0)	0.0 (0.0–1.0)	0.0 (0.0–0.0)	0.0 (0.0–2.5)	< 0.001
Cognitive IADLs	6.0 (3.5–8.5)	0.0 (0.0–1.0)	0.0 (0.0–0.0)	0.0 (0.0–2.0)	< 0.001
IQCODE-16	4.0 (3.8–4.6)	3.4 (3.2–3.7)	3.1 (3.0–3.3)	3.3 (3.1–3.8)	< 0.001
TMSE	22.0 (21.0–25.0)	28.0 (26.0–29.0)	28.0 (27.0–29.5)	27.0 (24.0–29.0)	< 0.001
Clock drawing test (paper)	6.0 (5.0–10.0)	10.0 (10.0–10.0)	10.0 (9.3–10.0)	10.0 (7.0–10.0)	< 0.001

Data are n (%) or median (IQR) unless stated. P values summarize between-group comparisons; statistical methods are described in Methods.

Abbreviations: ADLs, activities of daily living; Clox, digitized clock drawing; e-TMSE, electronic Thai Mental State Examination; IADLs, instrumental activities of daily living; IQCODE-16, 16-item Informant Questionnaire on Cognitive Decline in the Elderly; IQR, interquartile range; MCI, mild cognitive impairment; TMSE, Thai Mental State Examination

Digital and Standard Cognitive Screening Tests

The paper-and-pencil TMSE and the e-TMSE showed a strong, statistically significant correlation (Spearman's $\rho = 0.837$, $p < 0.001$), indicating that the digital version reflects the traditional assessment. The mean paper-and-pencil TMSE score was 26.04 ± 3.87 (median = 27), while the e-TMSE mean was 24.91 ± 4.18 (median = 25). Subdomain analysis showed comparable performance across most cognitive components. The score distribution indicated a population predominantly comprising cognitively intact individuals and those with mild cognitive impairment. Details are provided in **Table 2**.

Table 2. Paper-and-pencil TMSE vs electronic TMSE (e-TMSE): total and subdomain scores

TMSE components	Paper-based Mean $\pm$ SD (median)	Web-based Mean $\pm$ SD (median)	Correlation (Spearman's ρ)	p value
Total TMSE score	26.04 ± 3.87 (27)	24.91 ± 4.18 (25)	0.837	0.001
Orientation	5.11 ± 1.21 (6)	5.11 ± 1.21 (6)	0.818	0.001
Registration	2.96 ± 0.19 (3)	2.88 ± 0.32 (3)	-0.102	0.392
Attention	4.79 ± 0.92 (5)	4.75 ± 0.96 (5)	0.689	0.001
Calculation	2.20 ± 0.97 (2)	2.03 ± 1.00 (2)	0.993	0.001
Language	9.58 ± 1.01 (9)	8.88 ± 1.28 (9)	0.533	0.001
Recall	2.80 ± 0.40 (3)	2.68 ± 0.58 (3)	0.691	0.001

Values are mean $\pm$ SD and median (IQR) as appropriate. The total-score correlation between versions was Spearman's $\rho = 0.837$ ($p < 0.001$). See Methods for scoring details.

Abbreviations: e-TMSE, electronic Thai Mental State Examination; IQR, interquartile range; SD, standard deviation; TMSE, Thai Mental State Examination

Phase III: Full Study Implementation

A total of 198 participants were classified into three diagnostic groups: dementia ($n = 44$), mild cognitive impairment ($n = 58$), and cognitively normal controls ($n = 96$). This total was lower than the planned 246 from the prevalence-based calculation. The median age differed significantly across the groups ($p < 0.001$). Participants with dementia were older (median = 73 years; IQR = 69.25–79) and had the highest proportion with only primary education (68.2%). Cognitive and functional measures differed significantly across all assessments ($p < 0.001$). Median e-TMSE scores were lowest in the dementia group (18.5; IQR = 12.0–22.0) and highest in cognitively normal controls (26.0; IQR = 23.0–28.0). The scores for the Clox test and the category VFT showed a similar pattern. **Table 3** presents baseline participant characteristics.

Table 3. Baseline demographics and clinical characteristics, full implementation sample (n = 198)

Subject characteristics	Dementia (n = 44)	MCI (n = 58)	Normal cognition (n = 96)	Total (n = 198)	p value
Age (years)	73 (69.25–79)	69.5 (62.75–75)	65.5 (52–74)	69.5 (59–76)	< 0.001
Female (%)	32 (72.7%)	36 (62.1%)	69 (71.9%)	137 (69.2%)	0.375
Formal education level					
- Primary	30 (68.2%)	19 (32.8%)	36 (37.5%)	85 (42.9%)	
- Secondary	4 (9.1%)	8 (13.8%)	13 (13.5%)	25 (12.6%)	
- Vocational	3 (6.8%)	5 (8.6%)	9 (9.4%)	17 (8.6%)	
- Bachelor's degree	5 (11.4%)	22 (37.9%)	30 (31.3%)	57 (28.8%)	
- Postgraduate/graduate	2 (4.5%)	4 (6.9%)	8 (8.3%)	14 (7.1%)	
e-TMSE	18.5 (12.0–22.0)	25.0 (23.0–28.0)	26.0 (23.0–28.0)	24 (20–28)	< 0.001
Clox test	3.0 (0.0–8.0)	9.0 (7.0–10.0)	10.0 (8.0–10.0)	9 (6–10)	< 0.001
Verbal fluency test	7.0 (5.0–12.8)	14.0 (9.0–19.0)	17.5 (13.0–17.5)	15 (9–19)	< 0.001
Basic ADLs	8.0 (3.0–14.8)	0.0 (0.0–2.0)	0.0 (0.0–0.0)	0 (0–3)	< 0.001
Cognitive IADLs	8.0 (3.0–12.0)	0.0 (0.0–2.0)	0.0 (0.0–0.0)	0 (0–2)	< 0.001
IQCODE-16	4.3 (3.9–4.9)	3.3 (3.1–3.8)	3.3 (3.0–3.3)	3.4 (3.1–3.9)	< 0.001

Data are n (%), mean $\pm$ SD, or median (IQR) as appropriate. Diagnostic groups: major neurocognitive disorder, MCI, cognitively normal controls. Statistical methods are described in Methods.

Abbreviations: ADLs, activities of daily living; Clox, digitized clock drawing; e-TMSE, electronic Thai Mental State Examination; IADLs, instrumental activities of daily living; IQCODE-16, 16-item Informant Questionnaire on Cognitive Decline in the Elderly; IQR, interquartile range; MCI, mild cognitive impairment; SD, standard deviation

Digital Cognitive Test: e-TMSE and Cognitive Assessment

Figure 5 illustrates the correlation matrix showing associations between the e-TMSE and related cognitive and functional assessments. Positive correlations were observed between the e-TMSE and the paper-and-pencil CDT ($r = 0.501$) and the category VFT ($r = 0.565$), indicating convergence with other cognitive measures. In contrast, negative correlations were found between the e-TMSE and informant-reported or functional measures, including the IQCODE-16 ($r = -0.637$) and the ADL score ($r = -0.706$). These patterns reflect inverse relationships between cognitive performance and functional independence.

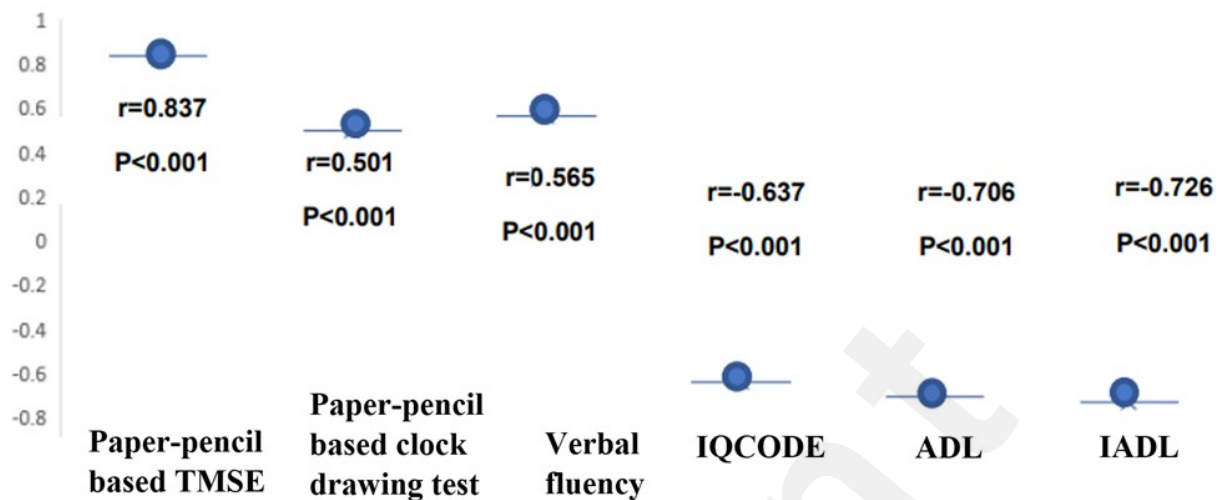


Fig. 5. Correlation matrix of digital cognitive and functional measures. Cells display Spearman's ρ among e-TMSE, the Clox test, category verbal fluency test, IQCODE-16, ADL, and cognitive IADLs. P values and analytic details appear in Methods.

Analysis of Cognitive and Functional Assessment for Dementia Screening

We conducted ROC analyses to evaluate the web-based application's diagnostic accuracy for distinguishing cognitively normal individuals from those with major neurocognitive disorder. **Figure 6** shows the ROC curves, and **Table 4** summarizes the performance metrics. The AUC values were as follows: e-TMSE (0.842), Clox test (0.774), category VFT (0.785), IQCODE-16 (0.884), ADL (0.901), and cognitive IADLs (0.906). Among these, cognitive IADLs and ADL showed the highest discriminatory power. The e-TMSE yielded an optimal cutoff score of ≤ 23 , with a sensitivity of 88.64% and a specificity of 70.13%. The details are provided in **Table 4**.

Table 4. Diagnostic performance of Healthy Brain Test digital measures for major neurocognitive disorder

Test	Maximum score	AUROC (95% CI)	Cutoff	Sensitivity (%)	Specificity (%)	Positive LR	Negative LR
e-TMSE	30	0.842 (0.784–0.890)	≤ 23	88.64	70.13	2.97	0.16
Clox test	10	0.774 (0.710–0.830)	≤ 7	68.17	75.32	2.76	0.42
Verbal fluency test	–	0.785 (0.721–0.840)	≤ 11	70.73	74.03	2.80	0.37
IQCODE-16	–	0.884 (0.831–0.925)	> 3.562	88.64	75.32	3.59	0.15
Basic ADLs	–	0.901 (0.850–0.939)	> 3	72.73	92.86	10.18	0.29
Cognitive IADLs	–	0.906 (0.857–0.943)	> 1	84.09	75.32	3.59	0.15

For each measure, the table reports AUC (95% CI), optimal cutoff, sensitivity, specificity, and likelihood ratios. Study-specific cutoffs: e-TMSE ≤ 23 ; Clox test ≤ 7 ; category verbal fluency test ≤ 11 ; IQCODE-16 > 3.562 ; ADLs > 3 ; cognitive IADLs > 1 . ROC procedures are described in Methods.

Abbreviations: ADLs, activities of daily living; AUROC, area under the receiver operating characteristic curve; CI, confidence interval; Clox, digitized clock drawing; e-TMSE, electronic Thai Mental State Examination; IQCODE-16, 16-item Informant Questionnaire on Cognitive Decline in the Elderly; IADLs, instrumental activities of daily living; LR, likelihood ratio; ROC, receiver operating characteristic

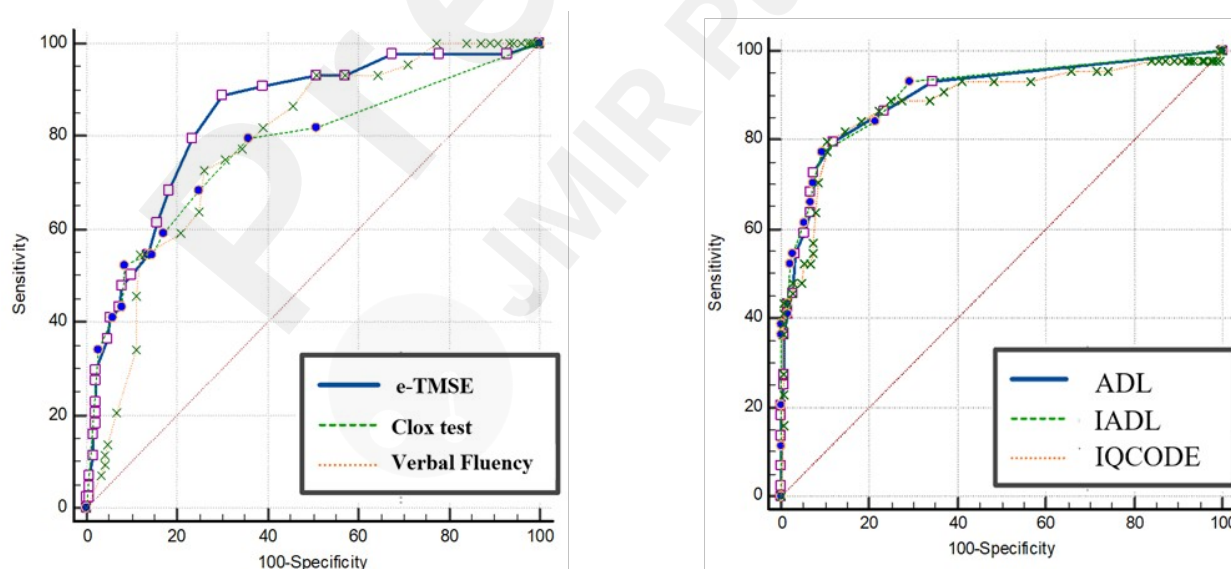


Fig. 6. ROC curves for digital measures distinguishing major neurocognitive disorder. Curves are shown for e-TMSE, Clox test, category verbal fluency test, IQCODE-16, ADL, and cognitive IADLs. AUC values, 95% CIs, and operating thresholds appear in Table 4.

Discussion

Web-based cognitive screening applications are a promising approach for early detection of cognitive impairment, particularly in resource-limited settings such as Thailand. We evaluated the feasibility and diagnostic accuracy of digitizing established neuropsychological assessments—the TMSE, clock drawing, verbal fluency, IQCODE-16, and ADL functional evaluations—into a web-based format. Our findings suggest that these web-based tools can reliably identify cognitive impairment and provide screening performance comparable to traditional paper-and-pencil methods.

The TMSE, culturally adapted from the Mini-Mental State Examination, is widely used in Thailand as a standard cognitive screening tool for dementia. It evaluates orientation, attention, memory, language, and visuospatial abilities, and prior validation studies report 85%–90% sensitivity and 80%–90% specificity for detecting dementia in Thai populations [15].

This study developed and evaluated a web-based TMSE adaptation (e-TMSE) that preserved the original assessment structure and scoring criteria. Using a diagnostic cutoff of ≤ 23 , the e-TMSE achieved AUC = 0.84 (95% CI 0.78–0.89), indicating a high level of discriminative ability for identifying dementia. Sensitivity and specificity were 88.64% and 70.13%, respectively, and were comparable to those of the traditional TMSE. In addition, e-TMSE scores correlated significantly with paper-and-pencil TMSE scores ($r = 0.837$, $p < 0.001$), supporting the concurrent validity of the digital format. Subdomain analyses showed comparable diagnostic performance across most cognitive components, although slight discrepancies were noted in registration and language. These discrepancies may reflect user interaction with the digital interface, particularly among participants with limited touchscreen experience.

The CDT is a brief, effective screening tool for visuoconstructional skills and executive function, which are commonly impaired in dementia. Prior studies report 76%–85% sensitivity and 81%–86% specificity for detecting dementia [22]. In our web-based adaptation, the Clox test achieved AUC = 0.77 (95% CI 0.71–0.83) with a cutoff of ≤ 7 ; sensitivity was 68.17%, and specificity was 75.32%. Although these values are somewhat lower than some traditional CDT benchmarks, they indicate moderate diagnostic accuracy and support digital screening utility. Performance differences may reflect technological literacy, touchscreen familiarity, and fine motor skills, which can influence task execution and response accuracy in older adults.

The VFT assesses executive function and lexical retrieval. Our implementation used the category (semantic) variant and showed AUC = 0.79 (95% CI 0.72–0.84) with a cutoff of ≤ 11 . Sensitivity was 70.73%, and specificity was 74.03%, indicating moderate diagnostic accuracy. Semantic fluency, particularly animal naming, is especially useful for early detection of cognitive impairment. Monsch et al. reported 100% sensitivity and 92.5% specificity for semantic fluency in distinguishing patients with Alzheimer's disease from cognitively normal controls [23]. Similarly, a meta-analysis by Henry and Crawford found that semantic fluency declines early in Alzheimer's disease and vascular cognitive impairment, reinforcing its role as an early diagnostic marker [24]. Furthermore, studies in individuals with mild cognitive impairment have shown that semantic fluency can be a sensitive and efficient screening tool for early stages of dementia [18, 25]. In addition to its diagnostic value, the VFT is simple to administer, cost-effective, and readily adaptable to digital formats. These features make it suitable for large-scale screening and for use in primary care or community-based settings.

The IQCODE provides complementary dementia screening by capturing caregiver-reported

longitudinal cognitive change and by circumventing patient insight deficits, which are common in dementia. Previous research reports 80%–90% sensitivity and specificity for distinguishing dementia from normal aging [26, 27]. In our study, the short-form IQCODE (IQCODE-16) showed a significant negative correlation with e-TMSE scores ($r = -0.637$, $p < 0.001$), consistent with earlier IQCODE–TMSE findings ($r = -0.679$, $p < 0.001$) [19]. This consistency supports the concurrent validity of the IQCODE-16 as a reliable screening instrument. IQCODE-16 achieved AUC = 0.88 (95% CI 0.83–0.93) with a cutoff of > 3.562 . Sensitivity was 88.64%, and specificity was 75.32%, with a marginally higher AUC than e-TMSE (AUC = 0.84). These findings highlight clinical relevance, particularly in community-based or resource-limited settings where cultural, educational, or language barriers may affect performance-based testing.

Functional assessments, especially ADL, provide essential context regarding the real-world impact of cognitive decline on daily functioning. Although not diagnostic in isolation, declines in ADL—particularly cognitive IADLs—are predictive of dementia progression. Our cognitive IADL component achieved AUC = 0.91 (95% CI 0.86–0.94) with a cutoff of > 1 ; sensitivity was 84.09%, and specificity was 75.32%. The ADL measure achieved AUC = 0.90 (95% CI 0.85–0.94) with a cutoff of > 3 ; sensitivity was 72.73%, and specificity was 92.86%. Adapting neuropsychological and functional assessments to web-based platforms, such as the *Healthy Brain Test*, represents meaningful progress in dementia screening. These platforms can expand access in resource-limited regions and facilitate earlier detection of cognitive decline. In Thailand, geographic and socioeconomic disparities limit access to specialized care, and a culturally adapted, validated digital tool may help bridge screening gaps in community-based settings.

The global adoption of mobile and web-based cognitive screening tools has expanded, offering promising alternatives to traditional paper-and-pencil assessments across clinical and community settings. The commercially available *BrainTest* reported 71% sensitivity and 90% specificity compared with comprehensive neuropsychological assessments [28]. Similarly, *M-CogScore*, which includes memory, attention, and executive tasks, achieved AUC = 0.85 (95% CI 0.80–0.91) and outperformed the MMSE-2 (AUC = 0.78, 95% CI 0.72–0.84) for distinguishing cognitively normal individuals from those with impairment [29]. In parallel, mobile cognitive screening tools designed for smartphones and tablets provide additional advantages over traditional modalities [30].

Nevertheless, important limitations persist. Wild et al. [30] noted that most self-administered electronic tools lack rigorous psychometric validation. Practical barriers include touchscreen usability challenges among older adults with limited digital experience, as well as broader issues of digital literacy. In addition, digital tools may be less able to detect subtle behavioral, emotional, or motivational cues that inform clinical assessment. These limitations are especially pronounced in resource-limited settings, where disparities in technology access and health services can further hinder effectiveness.

Thailand's cultural, linguistic, and socioeconomic factors require careful consideration when implementing web-based cognitive screening tools. Our study showed that the *Healthy Brain Test*, a web-based cognitive assessment application, is clinically useful for early detection of dementia. The tool demonstrated good psychometric performance and was validated across diverse Thai populations in multiple regions, strengthening the applicability of the findings. Several limitations warrant consideration. The sample comprised mostly individuals with normal cognition, mild cognitive impairment, and mild dementia, with limiting evaluation of performance in moderate to severe dementia. Most notably, the final sample size was lower than the planned target of 246, which may reduce the precision of estimates. Though, a 20% prevalence of dementia with a 95% CI and with the margin of error of about 5.6% led to the sample size of 198 in our study. Assessments were conducted under professional

supervision to ensure the understanding into local Thai pronunciation, which may not reflect real-world unsupervised use. Though caregivers can possibly play this role to help individual elders at home.

Future research should evaluate the *Healthy Brain Test* in unsupervised community-based settings, explore integration with digital health infrastructure, and enable longitudinal tracking of cognitive change. Implementation should be supported by healthcare professionals to ensure appropriate interpretation of results and timely referral for further evaluation or intervention.

Conclusion

This study demonstrates that the *Healthy Brain Test* web-based application is valid, efficient, and accessible for early detection of cognitive impairment. The battery comprised the e-TMSE, CDT, category VFT, the IQCODE-16, and ADL assessments. The digital test scores correlated strongly with traditional paper-and-pencil assessments, supporting the reliability and clinical applicability of our web based cognitive screening application. This simple, rapid tool is well suited for identifying cognitive impairment in primary care and community-based settings. Further studies should validate performance in unsupervised and diverse populations and support integration into routine cognitive health screening protocols.

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This study was partially supported by the Siriraj Foundation, Bangkok, Thailand.

Conflicts of interest

None declared.

Data Availability

The data supporting the findings of this study are available from the corresponding author upon reasonable request. Identifiable data are not publicly available due to privacy restrictions.

Authors' Contributions

VS conceptualized and designed the study, acquired funding, supervised the project, and led project administration, visualization, and manuscript review and editing. NW contributed to data curation, methodology development, supervision, validation, and supported formal analysis and project administration. SH conducted the formal analysis with support from NW. NP, SS, KT, and PK carried out the investigation and contributed to project administration and visualization. CR provided resources and participated in visualization and manuscript review. NP drafted the original manuscript under the supervision of VS. All authors reviewed, revised, and approved the final version of the manuscript.

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