Dement Neurocogn Disord. 2024 Oct;23(4):224-235
https://doi.org/10.12779/dnd.2024.23.4.224
pISSN 1738-1495·eISSN 2384-0757

DND Dementia and Neurocognitive Disorder

Original Article

Check for updates

Development of the Diagnostic Matrix of the Seoul Cognitive Status Test, Compared to Traditional Paper-and-Pencil Neuropsychological Tests

Seunghee Na [1,*] **Young Ju Kim** [2,3,*] **Si Eun Kim** [4] **Na-Yeon Jung** [5] **Seung Joo Kim** [6] **Hee Jin Kim** [2,7,8,9] **Joon Soo Shin** [3] **Duk L. Na** [3,10] **Sang Won Seo** [2,3,7,8,9] **Yeshin Kim** [11] **Eek-Sung Lee** [12]

[1]Department of Neurology, Incheon St. Mary's Hospital, The Catholic University of Korea, Incheon, Korea
[2]Department of Neurology, Samsung Medical Center, Sungkyunkwan University School of Medicine, Seoul, Korea
[3]Beaubrain Healthcare Co., Ltd., Seoul, Korea
[4]Department of Neurology, Inje University College of Medicine, Haeundae Paik Hospital, Busan, Korea
[5]Department of Neurology, Pusan National University Yangsan Hospital, Pusan National University School of Medicine, Yangsan, Korea
[6]Department of Neurology, Gyeongsang National University Changwon Hospital, Changwon, Korea
[7]Alzheimer's Disease Convergence Research Center, Samsung Medical Center, Seoul, Korea
[8]Neuroscience Center, Samsung Medical Center, Seoul, Korea
[9]Department of Health Sciences and Technology, Samsung Advanced Institute for Health Sciences & Technology (SAIHST), Sungkyunkwan University, Seoul, Korea
[10]Department of Neurology, Happymind Clinic, Seoul, Korea
[11]Department of Neurology, Kangwon National University Hospital, Kangwon National University College of Medicine, Chuncheon, Korea
[12]Department of Neurology, Soonchunhyang University Bucheon Hospital, Bucheon, Korea

Received: Sep 2, 2024
Revised: Oct 10, 2024
Accepted: Oct 10, 2024
Published online: Oct 23, 2024

Correspondence to
Yeshin Kim
Department of Neurology, Kangwon National University Hospital, Kangwon National University College of Medicine, 156 Baengnyeong-ro, Chuncheon 24289, Korea.
Email: yeshins@gmail.com

Eek-Sung Lee
Department of Neurology, Soonchunhang University Bucheon Hospital, 170 Jomaru-ro, Wonmi-gu, Bucheon 14584, Korea.
Email: eeksung@gmail.com

*Seunghee Na and Young Ju Kim have contributed equally to this work, and share the first authorship.

ORCID iDs
Seunghee Na
https://orcid.org/0000-0001-8578-8578
Young Ju Kim
https://orcid.org/0000-0003-2927-6724
Si Eun Kim
https://orcid.org/0000-0003-0429-5486

ABSTRACT

Background and Purpose: We aimed to develop the diagnostic matrix of the Seoul Cognitive Status Test (SCST) and compare its performance with traditional paper-and-pencil neuropsychological tests, including the Seoul Neuropsychological Screening Battery-II (SNSB-II) and the Korean version of the Consortium to Establish a Registry for Alzheimer's Disease (CERAD-K).
Methods: We recruited 197 participants from the head-to-head SCST-SNSB cohort, and 204 participants from the head-to-head SCST-CERAD cohort. They underwent either SNSB-II or CERAD-K, in addition to SCST. The diagnostic matrix was developed by combining cognitive function, determined by neuropsychological tests, and activities of daily living (ADL), determined by Instrumental-ADL scales.
Results: The diagnostic agreement between the SCST and the SNSB-II was 83.9% (weighted kappa=0.87). The agreement between the SCST and the CERAD-K was 84.3% (weighted kappa=0.88). In the SCST-SNSB cohort, all differences in SCST scores between the cognitively unimpaired (CU), mild cognitive impairment (MCI), and dementia diagnosed with the SNSB-II were significant in all cognitive domains (all $p<0.01$), except for the executive domain between CU and MCI ($p=0.145$). In the SCST-CERAD cohort, all differences in SCST scores between the 3 groups diagnosed with the CERAD-K were significant in all cognitive domains (all $p<0.01$), except for the language and visuospatial domains between MCI and dementia ($p=0.169$ and $p=0.778$, respectively).

Na-Yeon Jung
https://orcid.org/0000-0002-8265-9508
Seung Joo Kim
https://orcid.org/0000-0001-9391-1767
Hee Jin Kim
https://orcid.org/0000-0002-3186-9441
Joon Soo Shin
https://orcid.org/0000-0002-4641-6103
Duk L. Na
https://orcid.org/0000-0002-0098-7592
Sang Won Seo
https://orcid.org/0000-0002-8747-0122
Yeshin Kim
https://orcid.org/0000-0002-4643-5478
Eek-Sung Lee
https://orcid.org/0000-0003-3517-8207

Funding

This study was supported by grants from the Korean Health Technology R&D Project, Ministry of Health & Welfare, Republic of Korea (HI19C1132); the Korea Dementia Research Project through the Korea Dementia Research Center (KDRC), funded by the Ministry of Health & Welfare and Ministry of Science and ICT, Republic of Korea (grant number: RS-2020-KH106434); the Korea Health Technology R&D Project through the Korea Health Industry Development Institute (KHIDI), funded by the Ministry of Health & Welfare and the Ministry of Science and ICT, Republic of Korea (grant number: RS-2022-KH127756); the National Research Foundation of Korea (NRF), funded by the Korea government (MSIT) (NRF-2019R1A5A2027340); the Institute of Information & communications Technology Planning & Evaluation (IITP), funded by the Korea government (MSIT) (No. RS-2021-II212068, Artificial Intelligence Innovation Hub); the Future Medicine 20*30 Project of the Samsung Medical Center (#SMX1240561); and the "Korea National Institute of Health" research project (2024-ER1003-00).

Conflict of Interest

Duk L. Na and Sang Won Seo are scientific co-founders of BeauBrain Healthcare, a company aiming to commercialize the Seoul Cognitive Status Test. Young Ju Kim and Joon Soo Shin are employed at BeauBrain Healthcare. Duk L. Na, Sang Won Seo, and Joon Soo Shin had no role in the analysis and interpretation of the data. The remaining authors have no conflicts of interest to declare.

Conclusions: Our findings suggest that the tablet-based SCST may be another option to traditional paper-and-pencil neuropsychological tests, especially in situations where time and space are relatively limited, and neuropsychological testing specialists are not available.

Keywords: Diagnostic Matrix; Seoul Cognitive Status Test; Traditional Paper-and-Pencil Neuropsychological Tests; Head-to-Head Comparison; Tablet-Based

INTRODUCTION

Dementia remains one of the primary causes of death, ranking fifth among individuals over 65 years old.[1] The impact of dementia extends beyond the patients' lives to affect the physical and mental health of caregivers.[1] As the burden of dementia increases with disease progression,[2] detecting dementia early and intervening can be beneficial for both patients and their caregivers, potentially leading to significant cost reductions for healthcare systems. With the development of disease-modifying drugs, such as anti-amyloid monoclonal antibodies, in dementia, there is an emphasis on the importance of timely diagnosis, such as mild cognitive impairment (MCI), or mild degree of dementia, to improve health span.[3,4]

Diagnosis of dementia typically occurs when there are significant cognitive declines and impairments in the activities of daily living. Cognitive impairment could be detected before dementia symptoms become apparent.[5] If dementia symptoms are evident, a simple cognitive screening assessment, such as the Mini-Mental State Examination (MMSE), may be sufficient to screen for dementia in patients.[6] However, for patients with MCI or a mild degree of dementia, these screening tools have shown poor accuracy rates,[7] so neuropsychological batteries are necessary to identify the pattern and severity of cognitive impairment across different domains. Paper-and-pencil neuropsychological batteries, which are widely used, require expert neuropsychologists or healthcare professionals, a laboratory setting for examination, and a significant amount of time. Interpreting the results of neuropsychological assessments also requires specialized diagnostic knowledge in the field of dementia. Challenges such as cost, accessibility, and a shortage of experts may hinder primary care physicians from diagnosing patients with cognitive decline at an appropriate time.

Advances in technology have led to the development of various computerized cognitive assessment tools.[8] Digital cognitive tests offer several advantages, including the avoidance of human bias inherent in face-to-face interviews, reducing the workload of healthcare professionals, improving accessibility for cognitive assessment, and enabling accurate interpretation through data obtained from large databases.[8,9] Previously, we validated the tablet-based Seoul Cognitive Status Test (SCST), a computerized cognitive test battery.[10] Our findings suggested that the SCST exhibited good diagnostic performance for identifying amnestic MCI,[11] and showed high correlations and agreements of subtests with those of traditional paper-and-pencil neuropsychological batteries.[12] However, these processes have the disadvantage of requiring interpretation by dementia specialists. Considering that the SCST is a tool that could be used primarily by general physicians, there is a need for a diagnostic matrix that automatically classifies cognitive stages. Therefore, we developed a diagnostic matrix that could classify patients into cognitively unimpaired (CU), MCI, and dementia, based on the combination of the presence or absence of abnormalities in cognitive function and activities of daily living (ADL), based on the diagnostic criteria.

Author Contributions

Conceptualization: Na S, Kim YJ, Kim HJ, Na DL, Seo SW, Kim Y, Lee ES; Data curation: Na S, Kim SE, Jung NY, Kim SJ, Shin JS, Kim Y, Lee ES; Formal analysis: Kim YJ; Investigation: Na S, Shin JS; Methodology: Na S, Kim YJ, Kim Y, Lee ES; Supervision: Kim Y, Lee ES; Writing - original draft: Na S, Kim YJ, Shin JS; Writing - review & editing: Kim SE, Jung NY, Kim SJ, Kim HJ, Na DL, Seo SW, Kim Y, Lee ES.

In the present study, we aimed to validate the performances of the diagnostic matrix of the tablet-based SCST compared to traditional paper-and-pencil neuropsychological tests, including the Seoul Neuropsychological Screening Battery-II (SNSB-II) and the Korean version of the Consortium to Establish a Registry for Alzheimer's Disease (CERAD-K). First, we investigated the diagnostic agreements of the SCST with traditional paper-and-pencil neuropsychological tests, including the SNSB-II and the CERAD-K. Second, we determined whether there are differences in the SCST scores among the 3 cognitive stages of CU, MCI, and dementia diagnosed with traditional paper-and-pencil neuropsychological tests.

METHODS

Participants

The present study consisted of 2 cohorts: 1) the head-to-head SCST-SNSB cohort, and 2) the head-to-head SCST-CERAD cohort. These cohorts were recruited from the Korea Registries to Overcome and Accelerate Dementia Research Project (K-ROAD), which is a member of the worldwide Alzheimer's Disease Neuroimaging Initiative. Overall, 25 memory clinics and dementia prevention centers in South Korea participated in the K-ROAD cohort. Of them, 3 memory clinics and 9 dementia prevention centers took part in the present study. The SCST and SNSB head-to-head cohort consisted of a total of 197 individuals. In addition, the SCST and CERAD head-to-head cohort consisted of a total of 204 individuals (**Fig. 1**). The CU over 55 years had: 1) no history of neurologic or psychiatric disorders, and 2) normal cognitive function. The diagnosis of MCI was based on Petersen's criteria, including cognitive complaints from patients or caregivers, objective cognitive impairments, intact daily living activities, and the absence of dementia.[13] Dementia of Alzheimer's type followed the National Institute on Aging and Alzheimer's Association (NIA-AA) research criteria for probable Alzheimer's disease (AD).[14] The criteria for diagnosis with subcortical vascular dementia were as follows: 1) subjective cognitive complaints by the patient or caregiver; 2) objective cognitive impairment below the 16th percentile in any domain (including language, visuospatial, memory, or frontal function) upon neuropsychological testing; 3) impaired ADL, and 4) severe ischemia identified on

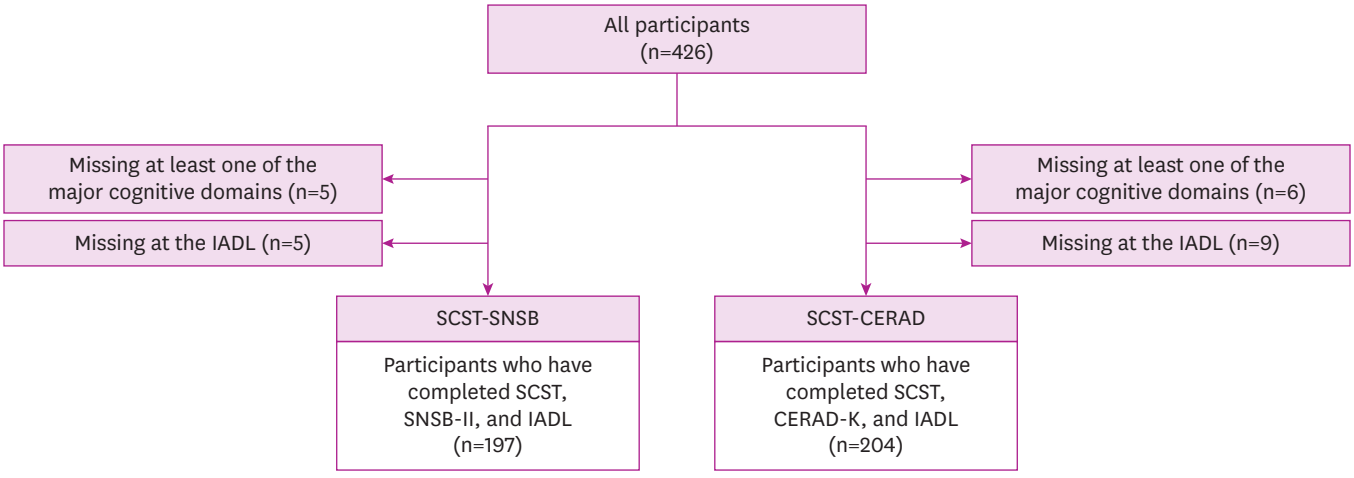

Fig. 1. Flow diagram for the study participant selection.
The present study consisted of 2 cohorts: head-to-head SCST-SNSB cohort, and head-to-head SCST-CERAD cohort. They underwent either SNSB-II or CERAD-K, in addition to SCST.
IADL: Instrumental Activities of Daily Living, SCST: Seoul Cognitive Status Test, SNSB-II: Seoul Neuropsychological Screening Battery-II, CERAD-K: Korean version of the Consortium to Establish a Registry for Alzheimer's Disease.

https://doi.org/10.12779/dnd.2024.23.4.224

brain magnetic resonance imaging, defined as the presence of periventricular white matter hyperintensities (WMH) >10 mm and deep WMH >25 mm, as modified from the Fazekas ischemia criteria.[15]

Assessments of neuropsychological tests

All participants underwent comprehensive neuropsychological tests, including either SNSB-II in the head-to-head SCST-SNSB cohort, or CERAD-K in the head-to-head SCST-CERAD cohort, in addition to SCST. The SCST, formally named Inbrain CST, was administered on a 12-inch tablet running Android application, and comprised 7 subtests assessing 5 core cognitive functions. The SCST was initially standardized on a sample of 478 CU elderly individuals in the Republic of Korea. Subsequently, 528 individuals were added to supplement the normative data, and re-standardization was recently completed with a sample of 1,006 CU elderly individuals (**Supplementary Table 1**). This included the forward and backward Visual Span Test for the attention domain, the Difficult Naming Test (DNT) and semantic (fruits)/phonemic (Korean alphabet digeut) word fluency test for the language domain, the Block Design Test (BDT) for visuospatial function domain, the time orientation tests and Word Place Association Test for the memory domain, and the Korean Trail-Making Test - Elderly version (K-TMT-E) parts A and B for the executive function domain. Age-, sex-, and education-specific norms were provided for each cognitive domain.[10] The present study used 8 subtests assessing 4 major cognitive domains included in the SNSB-II: the Korean version of the Boston Naming Test (K-BNT) and the Controlled Oral Word Association Test (animal and phonemic word fluency) for the language domain; the Rey Complex Figure Test (RCFT) copy for the visuospatial function domain; immediate recall, delayed recall, and recognition of the Seoul Verbal Learning Test-Elderly version for the memory domain; and the K-TMT-E parts A and B, as well as color reading of the Stroop test, for the executive function domain.[16] In addition, we used 8 subtests assessing 4 major cognitive domains included in the CERAD-K: Verbal Fluency (animal) and the K-BNT for the language domain; Constructional Praxis for the visuospatial function domain; Word List Memory, Word List Recall, and Word List Recognition for the memory domain; and K-TMT parts A and B, as well as color reading of the Stroop test for the executive function domain.[17] Normative data were stratified by age, sex, and educational background. We calculated the average of the z-score for subtests within each cognitive domain, and defined it as the cognitive domain scores of the SNSB-II or the CERAD-K. In addition, the average z-scores of the 4 cognitive domains were used as the total score of the SNSB-II or the CERAD-K.

Instrumental activities of daily living were assessed using either the Korean version of the Instrumental Activities of Daily Living (K-IADL) or the Seoul-Instrumental Activities of Daily Living (S-IADL) scale. The K-IADL is an 11-item questionnaire completed by caregivers, and functional impairment.[18] The S-IADL comprises 15 items, with scores ranging (0 to 45), with lower scores indicating better function.[19]

Development of diagnostic matrix

To classify our participants, we developed the diagnostic matrix in which the rows represented abnormalities of cognitive function determined by detailed neuropsychological tests, while the columns represented abnormalities of ADL determined by IADL scales (**Fig. 2**). In particular, since memory impairments are the most common symptom of AD, the most common cause of dementia, memory function, was assessed separately from cognitive function. The presence of cognitive impairments was determined by using cognitive scores below –1.0 standard deviation (SD) compared to age, sex, and education-adjusted norms in at least

https://doi.org/10.12779/dnd.2024.23.4.224

Diagnostic matrix				Instrumental ADL	
				Normal	Abnormal
Cognition Language Visuospatial Frontal	Normal	**Memory**	Normal	CU	NA
			Abnormal	Amnestic MCI	Dementia
	Abnormal	**Memory**	Normal	Non-amnestic MCI	Dementia
			Abnormal	Amnestic MCI	Dementia

Fig. 2. Diagnostic matrix of the SCST.
ADL: activities of daily living, CU: cognitively unimpaired, NA: not applicable, MCI: mild cognitive impairment.

one cognitive domain of neuropsychological tests. The ADL abnormalities were determined using a cut-off point of equal to or above 0.40 for the K-IADL, or 8 for the S-IADL.[18,19] Based on the diagnostic criteria, the participants were categorized into CU, MCI, and dementia according to the combination of the presence or absence of abnormalities in cognitive function and ADLs. We categorized participants with normal cognitive function but ADL abnormalities into the 'not applicable (NA)' group, and excluded them in the further analyses (SCST-SNSB cohort, NA=5; SCST-CERAD cohort, NA=19).

Statistical analyses

We calculated percent agreement and weighted kappa to confirm the concordance rate between those diagnosed with SCST and those diagnosed with SNSB-II, and between those diagnosed with SCST and those diagnosed with CERAD-K. We used weighted kappa to identify concordant cases with the same cognitively impaired classification by the SCST and the SNSB-II or the CERAD-K. Weighted kappa penalizes disagreements in terms of their seriousness, and is suitable for ordinal scales.[20] Analysis of covariance (ANCOVA) was also performed to identify the differences in the SCST score between CU, MCI, and dementia diagnosed by the SNSB-II or the CERAD-K, after controlling for covariates, including age, sex, and education level. The *p*-values were corrected for multiple tests using the Bonferroni method. We then calculated Cohen's *d* to determine the magnitude of the difference between the groups. While the *p*-value can inform whether an effect exists, since it does not reveal the size of the effect, both the substantive significance (effect size) and statistical significance (*p*-value) are essential results to be reported.[21] Finally, a sensitivity analysis was performed by adjusting the criteria for cognitive impairment by –1.5SD to verify the robustness of the diagnostic group using neuropsychological tests.

All analyses were performed using z-scores adjusted for age, education level, and sex, based on the original normative data from the initial 478 CU elderly individuals. In the analysis of ANCOVA and effect size, outliers were removed for variables indicating non-normality. All statistical analyses were performed using SPSS 24 (IBM Corp., Armonk, NY, USA) and R 4.2.1 package (R Foundation for Statistical Computing, Vienna, Austria; http://www.R-project.org/).

Ethics statement

Written informed consent was obtained from all participants, and the study was approved by the Institutional Review Board (IRB) of Soonchunhyang University Buchen Hospital (IRB approval No. 2020-03-016) & board of the public (Korea National Institute for Bioethics Policy) (IRB approval No. P01-202306-01-033).

https://doi.org/10.12779/dnd.2024.23.4.224

Table 1. Baseline demographic and clinical characteristics of the participants

Characteristics	SCST-SNSB cohort (n=197)	SCST-CERAD cohort (n=204)
Age (years)	71.1±8.3	72.0±8.4
Education (years)	13.6±4.1	9.4±4.5
Female	127 (64.5)	132 (64.7)
K-MMSE	24.9±4.4	23.3±4.8

The present study consisted of 2 cohorts: head-to-head SCST-SNSB cohort, and head-to-head SCST-CERAD cohort. They underwent either SNSB-II or CERAD-K, in addition to SCST. Values are presented as the mean ± standard deviation or number (%).
SCST: Seoul Cognitive Status Test, SNSB-II: Seoul Neuropsychological Screening Battery-II, CERAD-K: Korean version of the Consortium to Establish a Registry for Alzheimer's Disease, K-MMSE: Korean version of the Mini-Mental State Examination.

RESULTS

Characteristics of the study participants

Table 1 presents the characteristics of the study participants. The mean ages of the participants were 71.1 and 72.0 years in the SCST-SNSB and the SCST-CERAD cohorts, respectively. The average education levels were 13.6 years in the SCST-SNSB cohort, and 9.4 years in the SCST-CERAD cohort. The proportions of females were 64.5% in the SCST-SNSB cohort, and 64.7% in the SCST-CERAD cohort. In addition, the Korean version of the MMSE scores of the SCST-SNSB and SCST-CERAD were 24.9 and 23.3, respectively.

Diagnostic agreements between the SCST and the traditional neuropsychological tests

The diagnostic agreement between the SCST and the SNSB-II was 83.9%, yielding a weighted kappa value of 0.87. The agreement between the SCST and the CERAD-K was 84.3%, resulting in a weighted kappa value of 0.88 (**Fig. 3**). The weighted kappa of (0.87 to 0.88) indicate a strong level of agreement.[22] There seemed to be more cases classified as CU by the SNSB-II or the CERAD-K, but classified as MCI by the SCST, than those classified as MCI by the SNSB-II or the CERAD-K, but classified as CU by the SCST.

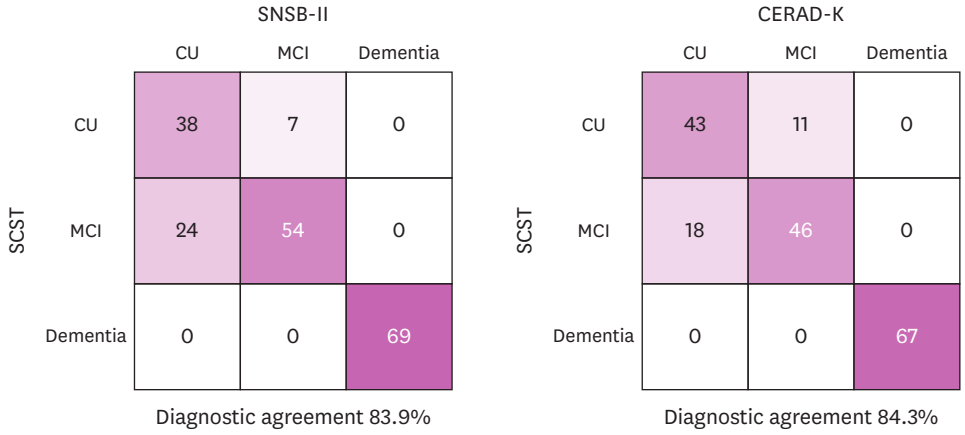

Fig. 3. Diagnostic agreement between the SCST and the traditional neuropsychological tests (cut-point –1.0SD). SNSB-II: Seoul Neuropsychological Screening Battery-II, CU: cognitively unimpaired, MCI: mild cognitive impairment, SCST: Seoul Cognitive Status Test, CERAD-K: Korean version of the Consortium to Establish a Registry for Alzheimer's Disease, SD: standard deviation.

https://doi.org/10.12779/dnd.2024.23.4.224

For a sensitivity analysis, when cognitive performance below –1.5SD was defined as cognitive impairment, the diagnostic agreement between the SCST and the SNSB-II was 82.4%, and that between the SCST and the CERAD-K was 82.2% (**Supplementary Fig. 1**).

SCST scores in the groups diagnosed with traditional neuropsychological results

Fig. 4 and **Supplementary Fig. 2** show the SCST scores in CU, MCI, and dementia diagnosed with the SNSB-II or the CERAD-K. In the SCST-SNSB cohort, all differences in SCST scores between the 3 groups were significant in all cognitive domains (all $p<0.01$), except for the executive domain between CU and MCI ($p=0.145$). For reference, all differences in SNSB-II scores between the 3 groups were also significant in all cognitive domains (all $p<0.01$), except for the visuospatial and executive function domains between CU and MCI ($p=0.083$ for visuospatial; $p=1.000$ for executive function). In addition, we observed a linear trend of decline as the stage advanced in both the SCST and the SNSB-II (SCST, p for trend <0.001; SNSB-II, p for trend <0.001).

In the SCST-CERAD cohort, all differences in SCST scores between the 3 groups were significant in all cognitive domains (all $p<0.01$), except for the language and visuospatial domains between MCI and dementia ($p=0.169$ for language; $p=0.778$ for visuospatial). For reference, all differences in CERAD-K scores between the 3 groups were also significant in all cognitive domains (all $p<0.01$), except for the visuospatial domain between MCI and dementia ($p=1.000$). We observed a linear trend of decline as the stage advanced in both the SCST and the CERAD-K (SCST, p for trend <0.001; CERAD-K, p for trend <0.001).

In a sensitivity analysis, when cognitive performance below –1.5SD was defined as cognitive impairment, the results were largely consistent with those obtained using the –1.0SD threshold in both the SCST-SNSB and SCST-CERAD cohorts. Specifically, the SCST scores across the 3 groups showed similar trends to the –1.0SD threshold (**Supplementary Fig. 3**).

Fig. 5 and **Supplementary Fig. 4** show the effect sizes in each domain and the total score of the SCST in CU, MCI, and dementia diagnosed with the SNSB-II or the CERAD-K. In the SCST-SNSB cohort, the effect size of CU versus MCI ranged from medium to very large (Cohen's d range: 0.61 to 1.47 for SCST scores and 0.74 to 2.46 for SNSB-II scores, respectively). The effect size of CU versus dementia showed more than a very large effect size in all cognitive domains (Cohen's d range: 1.27 to 2.71 for the SCST and 1.23 to 3.09 for the SNSB-II, respectively), except for the visuospatial domain in the SNSB-II (Cohen's $d=0.90$). In MCI versus dementia, all cognitive domains in the SCST had medium to large effect sizes (range, 0.54 to 1.05), while those in the SNSB-II had large effect sizes (range, 0.83 to 0.97) for the SNSB-II, except for the visuospatial domain (Cohen's $d=0.39$). In the SCST-CERAD cohort, the effect size of CU versus MCI ranged from large to very large (Cohen's d range: 0.88 to 1.77 for the SCST and 1.03 to 2.43 for the CERAD-K, respectively). In CU versus dementia, the SCST and the CERAD-K scores showed more than a very large effect size in most cognitive domains (Cohen's d range: 1.33 to 2.37 for SCST and 1.74 to 2.86 for CERAD-K, respectively). However, the CERAD-K showed a smaller effect size in the visuospatial domain than the SCST (Cohen's $d=0.81$). In MCI versus dementia, all cognitive domains were similar, with effect sizes ranging from small to large (range: 0.35 to 0.87 for the SCST and 0.42 to 0.80 for the CERAD-K, respectively).

https://doi.org/10.12779/dnd.2024.23.4.224

DND Dementia and Neurocognitive Disorder

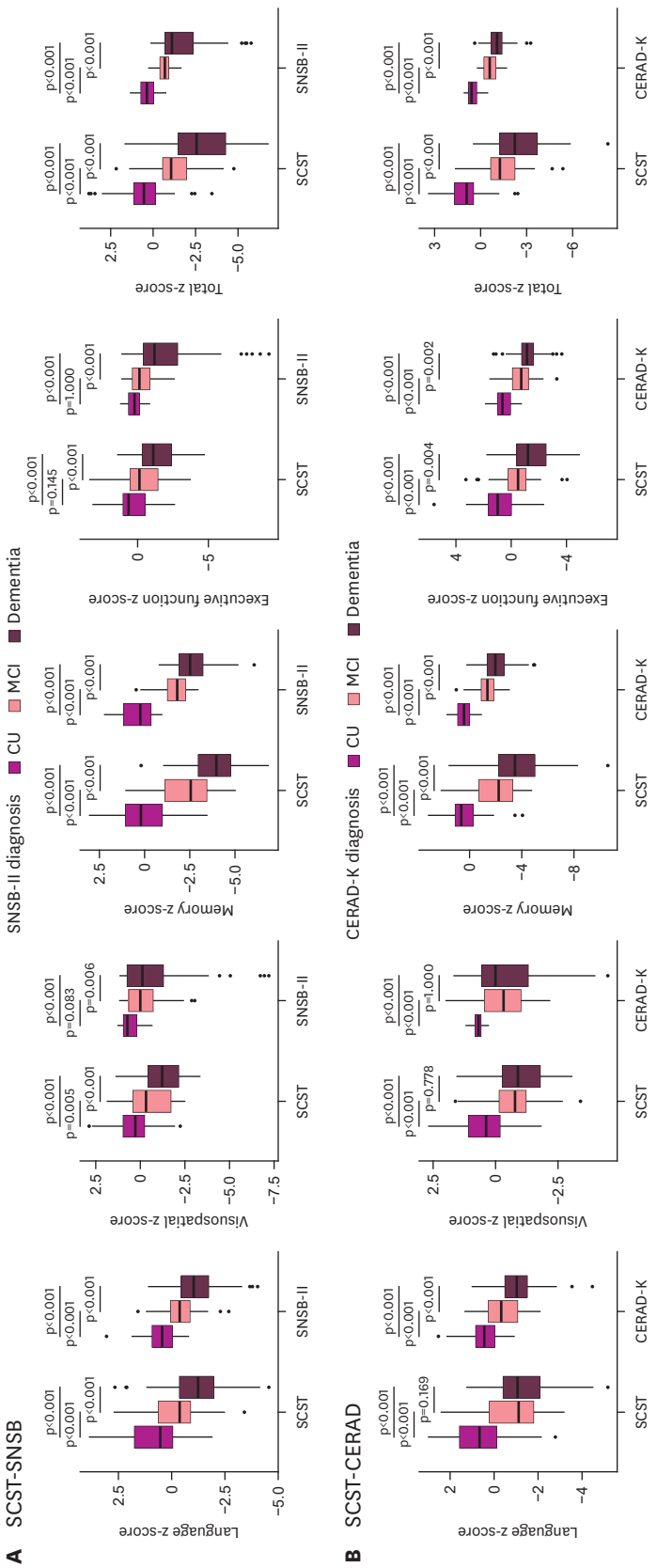

Fig. 4. Comparison of the SCST scores between the groups diagnosed with the SNSB-II or the CERAD-K (cut-point −1.0SD).
The present study consisted of 2 cohorts: head-to-head SCST-SNSB cohort, and head-to-head SCST-CERAD cohort. They underwent either SNSB-II or CERAD-K, in addition to SCST.
SCST: Seoul Cognitive Status Test, SNSB-II: Seoul Neuropsychological Screening Battery-II, CU: cognitively unimpaired, MCI: mild cognitive impairment, CERAD-K: Korean version of the Consortium to Establish a Registry for Alzheimer's Disease, SD: standard deviation.

https://doi.org/10.12779/dnd.2024.23.4.224

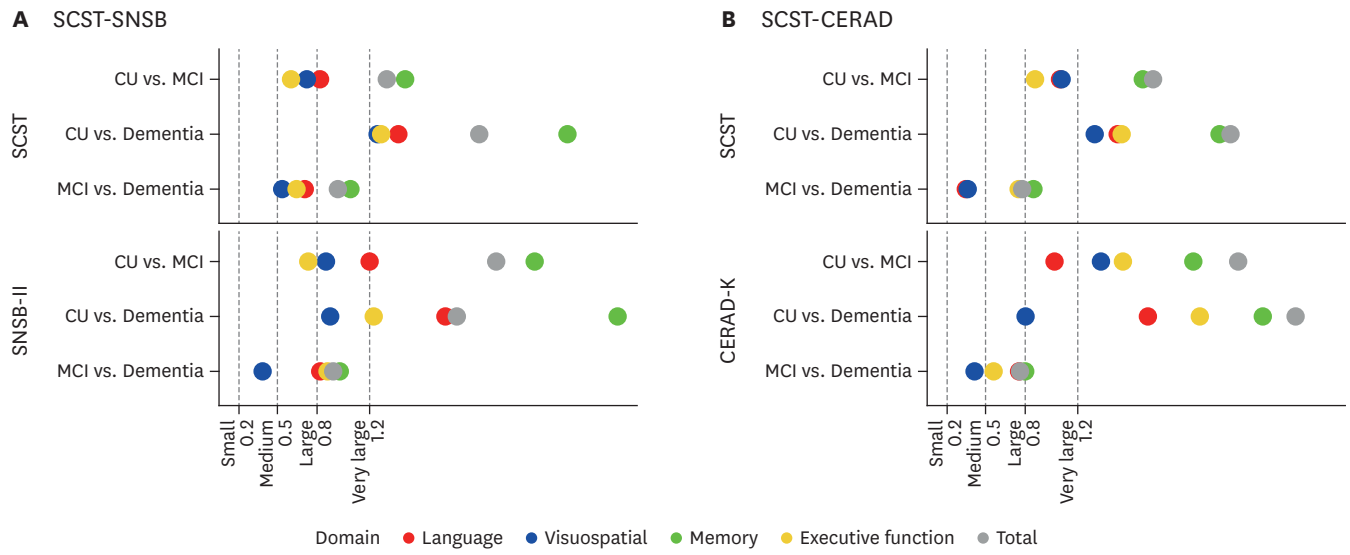

Fig. 5. Cohen's *d* of the SCST, the SNSB-II, and the CERAD-K.
The present study consisted of 2 cohorts: head-to-head SCST-SNSB cohort, and head-to-head SCST-CERAD cohort. They underwent either SNSB-II or CERAD-K, in addition to SCST.
SCST: Seoul Cognitive Status Test, SNSB-II: Seoul Neuropsychological Screening Battery-II, CERAD-K: Korean version of the Consortium to Establish a Registry for Alzheimer's Disease, CU: cognitively unimpaired, MCI: mild cognitive impairment.

DISCUSSION

In the present study, we developed the diagnostic matrix of the tablet-based SCST, and used the head-to-head SCST-SNSB and SCST-CERAD cohorts to validate the performances of their diagnostic matrix. We found that the SCST showed a strong level of agreement with traditional paper-and-pencil neuropsychological tests, including the SNSB-II and the CERAD-K. We also found that the SCST scores in each cognitive domain exhibited significant differences across the 3 cognitive stages diagnosed with traditional neuropsychological tests. Moreover, the overall effect size in the SCST was comparable to those of the SNSB-II and the CERAD-K. Taken together, our findings suggest that the tablet-based SCST may be another option to traditional paper-and-pencil neuropsychological tests, especially in situations where time and space are relatively limited, and neuropsychological testing specialists are not available.

Our first major finding was that the SCST showed a strong level of agreement with traditional paper-and-pencil neuropsychological tests, including the SNSB-II and the CERAD-K. To the best of our knowledge, head-to-head comparisons between computerized neuropsychological tests and traditional paper-and-pencil neuropsychological tests have not yet been extensively investigated. Previously, computerized cognitive batteries from Western countries have demonstrated relatively good diagnostic accuracy (area under the curve [AUC], 0.84 to 0.87) for distinguishing MCI from normal cognition,[23,24] and AUC (0.82 to 0.89) for distinguishing dementia from normal cognition.[25,26] However, unlike computerized cognitive batteries, our diagnostic matrix showed excellent performances in classifying cognitive stages of the CU, MCI, and dementia statuses. Given that the role of a comprehensive neuropsychological battery includes providing cognitive profiles across various cognitive functions, assessing objective cognitive status, and enabling comparison within individuals, the high diagnostic concordance of SCST from cognitively normal status to dementia aids physicians in monitoring cognitive function in patients and readily identifying changes in cognitive status. Previously, the digital

https://doi.org/10.12779/dnd.2024.23.4.224

versions of revised traditional tests have shown significant correlations with varying degrees ranging (0.31 to 0.90).[8] Therefore, rather than replacing traditional neuropsychological tests with their digital versions, it might be more effective to develop and configure neuropsychological test items for digital versions.

Various studies have used different cut-off points to determine the presence of cognitive impairments. In the present study, we used the cut-off point of –1.0SD, because it is important to detect cognitive impairments at an early stage. For sensitivity analysis, we also used –1.5SD as the cut-off point, because different cut-off points could affect the diagnostic agreements. However, the results were similar to those when –1.0SD was used as the cut-off point. Recognizing the importance of detecting MCI patients to prevent dementia progression, establishing the threshold at –1.0SD may be considered appropriate to monitor cognitive decline.

Our second major finding was that the SCST scores in each cognitive domain exhibited significant differences across the 3 cognitive stages diagnosed with traditional neuropsychological tests. Moreover, the overall effect size in the SCST was comparable to those of the SNSB-II and the CERAD-K. We found that the SCST was better at distinguishing visuospatial functions between CU and MCI, when compared to the SNSB-II. The SCST's BDT, enhanced by its digital interface, allows for precise, automated tracking of time and errors, providing a more detailed assessment than the manual scoring of the SNSB-II's RCFT. The computerized format of the SCST reduces human error, and increases sensitivity in detecting subtle visuospatial impairments. Regarding the SCST's relative inefficiency in distinguishing language functions between MCI and dementia compared to the CERAD-K, the CERAD-K includes comprehensive language tasks, like verbal fluency and K-BNT, which are more sensitive to language deficits across cognitive decline. In contrast, the SCST uses the DNT and semantic/phonemic word fluency tasks, which may be less sensitive at later stages. Additionally, since the SCST already effectively differentiates language functions between CU and MCI, this may reduce its ability to show further differences between MCI and dementia. These discrepancies might also be related to differences in the characteristics of paper-and-pencil neuropsychological tests and computerized neuropsychological tests. Furthermore, given that the SCST takes less time to perform, does not necessarily require a neuropsychologist, and could be easily interpreted compared to paper-and-pencil neuropsychological tests, our findings suggest that the SCST could be another option for neuropsychological testing in primary care, as well as memory clinics.

We did not find any difference between CU and MCI in the executive function domains in both the SCST and SNSB-II, and no difference between MCI and dementia in the visuospatial domain in both the SCST and CERAD-K. This might be related to the low proportion of non-amnestic MCI (7.3%). In this study, we focused on 4 cognitive domains—memory, language, visuospatial, and executive functions—excluding attention for consistency across the SCST, SNSB-II, and CERAD-K. In the CERAD-K, TMT-A and Stroop word reading are part of the attention domain, while in SCST and SNSB-II, they fall under executive function. Additionally, attention is not a core domain to diagnose MCI, supporting its exclusion. This approach allowed better alignment of the domains relevant to MCI diagnosis, while ensuring accurate comparisons across the tests.

The strengths of this study are that we recruited a relatively large number of participants from a variety of sources, including large and small cities, memory clinics, and dementia prevention centers, and performed a head-to-head comparison between tablet-based tests and traditional pencil and paper tests. However, the present study has several limitations. First, there were differences in the educational levels between the SCST-SNSB and the

SCST-CERAD cohorts. However, this argument might be mitigated by the results that the diagnostic agreements between the SCST and the SNSB-II were very similar to those between the SCST and the CERAD-K. Second, due to the small number of non-amnestic MCI patients in the present study, it was not possible to separate amnestic and non-amnestic MCI in the diagnostic matrix. Further studies with more non-amnestic MCI patients are needed to validate the various functions of this diagnostic matrix. Finally, we did not include participants with late stages of dementia. Patients with late stages of dementia have difficulties in performing the traditional neuropsychological tests, as well. Therefore, our detailed traditional and tablet-based neuropsychological tests may be better suited to diagnose patients with MCI or early stages of dementia. Nevertheless, our study is worth reporting, because it shows that the diagnostic matrix of tablet-based neuropsychological tests has a high concordance with those of traditional neuropsychological tests.

In conclusion, our findings suggest that the newly developed diagnostic matrix of tablet-based SCST showed a strong level of agreement with traditional paper-and-pencil neuropsychological tests. Furthermore, differences in the SCST scores between the groups diagnosed with traditional paper-and-pencil neuropsychological tests were comparable to those in the traditional neuropsychological scores between the groups. Therefore, given the advantages of computerized tests, SCST could be another option for neuropsychological testing in primary care, as well as in memory clinics.

SUPPLEMENTARY MATERIALS

Supplementary Table 1
Updated mean and standard deviation of cognitive domains and total scores by age, sex, and educational level in the SCST (n=1,006)

Supplementary Fig. 1
Diagnostic agreement between the SCST and the traditional neuropsychological tests (cut-point –1.5SD).

Supplementary Fig. 2
Comparison of the SCST attention scores between the groups diagnosed with the SNSB-II or the CERAD-K.

Supplementary Fig. 3
Comparison of the SCST scores between the groups diagnosed with the SNSB-II or the CERAD-K (cut-point –1.5SD).

Supplementary Fig. 4
Cohen's *d* of the SCST, the SNSB-II, and the CERAD-K.

REFERENCES

1. 2023 Alzheimer's disease facts and figures. Alzheimers Dement 2023;19:1598-1695. PUBMED | CROSSREF
2. Leicht H, Heinrich S, Heider D, Bachmann C, Bickel H, van den Bussche H, et al. Net costs of dementia by disease stage. Acta Psychiatr Scand 2011;124:384-395. PUBMED | CROSSREF

3. Waldemar G, Phung KT, Burns A, Georges J, Hansen FR, Iliffe S, et al. Access to diagnostic evaluation and treatment for dementia in Europe. Int J Geriatr Psychiatry 2007;22:47-54. PUBMED | CROSSREF
4. Dubois B, Padovani A, Scheltens P, Rossi A, Dell'Agnello G. Timely diagnosis for Alzheimer's disease: a literature review on benefits and challenges. J Alzheimers Dis 2016;49:617-631. PUBMED | CROSSREF
5. Then FS, Luck T, Luppa M, König HH, Angermeyer MC, Riedel-Heller SG. Differential effects of enriched environment at work on cognitive decline in old age. Neurology 2015;84:2169-2176. PUBMED | CROSSREF
6. Tsoi KK, Chan JY, Hirai HW, Wong SY, Kwok TC. Cognitive tests to detect dementia: a systematic review and meta-analysis. JAMA Intern Med 2015;175:1450-1458. PUBMED | CROSSREF
7. Breton A, Casey D, Arnaoutoglou NA. Cognitive tests for the detection of mild cognitive impairment (MCI), the prodromal stage of dementia: meta-analysis of diagnostic accuracy studies. Int J Geriatr Psychiatry 2019;34:233-242. PUBMED | CROSSREF
8. Chan JY, Yau ST, Kwok TC, Tsoi KK. Diagnostic performance of digital cognitive tests for the identification of MCI and dementia: a systematic review. Ageing Res Rev 2021;72:101506. PUBMED | CROSSREF
9. Sternin A, Burns A, Owen AM. Thirty-five years of computerized cognitive assessment of aging-where are we now? Diagnostics (Basel) 2019;9:114. PUBMED | CROSSREF
10. Chin J, Kim DE, Lee H, Yun J, Lee BH, Park J, et al. A validation study of the Inbrain CST: a tablet computer-based cognitive screening test for elderly people with cognitive impairment. J Korean Med Sci 2020;35:e292. PUBMED | CROSSREF
11. Na S, Lee ES, Lee TK. Diagnostic performance of a tablet computer-based cognitive screening test for identification of amnestic mild cognitive impairment. J Korean Med Sci 2023;38:e131. PUBMED | CROSSREF
12. Na S, Seo SW, Kim YJ, Yoo H, Lee ES. Correlation analysis between subtest scores of CERAD-K and a newly developed tablet computer-based digital cognitive test (Inbrain CST). Front Aging Neurosci 2023;15:1178324. PUBMED | CROSSREF
13. Petersen RC. Mild cognitive impairment as a diagnostic entity. J Intern Med 2004;256:183-194. PUBMED | CROSSREF
14. Jack CR Jr, Bennett DA, Blennow K, Carrillo MC, Dunn B, Haeberlein SB, et al. NIA-AA Research Framework: toward a biological definition of Alzheimer's disease. Alzheimers Dement 2018;14:535-562. PUBMED | CROSSREF
15. Fazekas F, Kleinert R, Offenbacher H, Schmidt R, Kleinert G, Payer F, et al. Pathologic correlates of incidental MRI white matter signal hyperintensities. Neurology 1993;43:1683-1689. PUBMED | CROSSREF
16. Kang Y, Jahng S, Na DL. *Seoul Neuropsychological Screening Battery. Second Edition (SNSB-II): Professional Manual.* Seoul: Human Brain Research & Consulting Co., 2012.
17. Lee JH, Lee KU, Lee DY, Kim KW, Jhoo JH, Kim JH, et al. Development of the Korean version of the Consortium to Establish a Registry for Alzheimer's Disease Assessment Packet (CERAD-K): clinical and neuropsychological assessment batteries. J Gerontol B Psychol Sci Soc Sci 2002;57:47-53. PUBMED | CROSSREF
18. Chin J, Park J, Yang SJ, Yeom J, Ahn Y, Baek MJ, et al. Re-standardization of the Korean-Instrumental Activities of Daily Living (K-IADL): clinical usefulness for various neurodegenerative diseases. Dement Neurocogn Disord 2018;17:11-22. PUBMED | CROSSREF
19. Ku HM, Kim JH, Kwon EJ, Kim SH, Lee HS, Ko HJ, et al. A study on the reliability and validity of Seoul-Instrumental Activities of Daily Living (S-IADL). J Korean Neuropsychiatr Assoc 2004;43:189-199.
20. Sim J, Wright CC. The kappa statistic in reliability studies: use, interpretation, and sample size requirements. Phys Ther 2005;85:257-268. PUBMED | CROSSREF
21. Sullivan GM, Feinn R. Using effect size—or why the P value is not enough. J Grad Med Educ 2012;4:279-282. PUBMED | CROSSREF
22. Sawilowsky SS. New effect size rules of thumb. J Mod Appl Stat Methods 2009;8:597-599. CROSSREF
23. Ahmed S, de Jager C, Wilcock G. A comparison of screening tools for the assessment of mild cognitive impairment: preliminary findings. Neurocase 2012;18:336-351. PUBMED | CROSSREF
24. Dwolatzky T, Whitehead V, Doniger GM, Simon ES, Schweiger A, Jaffe D, et al. Validity of a novel computerized cognitive battery for mild cognitive impairment. BMC Geriatr 2003;3:4. PUBMED | CROSSREF
25. Doniger GM, Zucker DM, Schweiger A, Dwolatzky T, Chertkow H, Crystal H, et al. Towards practical cognitive assessment for detection of early dementia: a 30-minute computerized battery discriminates as well as longer testing. Curr Alzheimer Res 2005;2:117-124. PUBMED | CROSSREF
26. Mundt JC, Ferber KL, Rizzo M, Greist JH. Computer-automated dementia screening using a touch-tone telephone. Arch Intern Med 2001;161:2481-2487. PUBMED | CROSSREF