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Original Article

Validity of the Montreal Cognitive Assessment (MoCA) Index Scores: a Comparison with the Cognitive Domain Scores of the Seoul Neuropsychological Screening Battery (SNSB)

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Conflict of Interest
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ABSTRACT

Background and Purpose: A new approach was proposed to score the Montreal Cognitive Assessment (MoCA) index scores for 6 cognitive domains: orientation (OIS), attention (AIS), language (LIS), visuospatial function (VIS), memory (MIS), and executive function (EIS). This study investigated whether the MoCA index scores represent the functions of each cognitive domain by examining the correlations with the corresponding cognitive domain scores derived from conventional neuropsychological tests included in the Seoul Neuropsychological Screening Battery, 2nd Edition (SNSB-II).
Methods: The participants were 104 amnestic mild cognitive impairment (aMCI), 74 vascular mild cognitive impairment (VaMCI), 73 dementia of the Alzheimer's type (DAT), and 41 vascular dementia (VaD) patients. All participants were administered the Korean-MoCA and SNSB-II.
Results: Like the MoCA total score, the MoCA-OIS, MoCA-VIS, and MoCA-MIS showed differences between aMCI and AD groups and between VaMCI and VaD groups. The MoCA-AIS, MoCA-LIS, and MoCA-EIS showed significant differences between VaMCI and VaD groups, but no difference between aMCI and DAT groups. In the aMCI and VaMCI groups, all index scores of the MoCA showed significant correlations with the corresponding cognitive domain scores of the SNSB-II. Except for MoCA-MIS, the MoCA-AIS, MoCA-LIS, MoCA-VIS, and MoCA-EIS also showed significant correlations with the corresponding domain scores of the SNSB-II in the DAT and VaD groups.
Conclusions: These results indicate that all MoCA index scores, except for MoCA-MIS, which does not reflect the severity of memory impairment in dementia patients, provide highly valid information on the function of each cognitive domain in patients with mild cognitive impairment and dementia.

Keywords: Montreal Cognitive Assessment; Mild Cognitive Impairment; Dementia

DND Dementia and Neurocognitive Disorder

Author Contributions

Conceptualization: Kang Y; Data curation: Kim H, Kang Y; Formal analysis: Kim H; Funding acquisition: Kang Y; Investigation: Kim H, Kang Y; Methodology: Kim H, Kang Y; Project administration: Kang Y; Writing - original draft: Kim H; Writing - review & editing: Kim H, Yu KH, Lee BC, Kim BC, Kang Y.

INTRODUCTION

The Montreal Cognitive Assessment (MoCA) is a cognitive screening test used internationally. It was originally developed for the screening of mild cognitive impairment (MCI), which converts to Alzheimer's disease (AD).[1] However, it has also been useful for assessing vascular cognitive impairment (VCI)[2,3] and cognitive impairment in Parkinson's disease[4] since it proportionally involves many subtests for assessing frontal and executive function.[5]

Recently, Julayanont et al.[6] proposed MoCA index scores for the six cognitive domains comprising subtests of the MoCA: orientation, attention, language, visuospatial function, memory, and executive function. In their study, In their study, they produced cut-off scores that predicted MCI conversion to AD. They reported that 90.5% of patients with both scores below the cutoff for impairment–total score (20/30 points) and memory index score (7/15 points)–converted to AD, whereas 74.5% converted when one of two scores was below the cutoff. Kaur et al.[7] found that MoCA memory index score was better at discriminating amnestic MCI (aMCI) from normal cognition than the paragraph recall. Goldstein et al.[8] investigated effect sizes of the MoCA total and index scores in differentiating individuals with healthy cognition from those with MCI or AD. In distinguishing healthy individuals from MCI, the total MoCA score had stronger incremental validity than the index scores, and a combined index score was more informative than the individual index scores. Some studies were conducted to confirm the differences between clinical groups through the MoCA index score. Wood et al.[9] showed that memory and orientation index scores were lowest in the AD group, whereas language and attention index scores were lowest in primary progressive aphasia (PPA). Another study used the MoCA index score for detection of cognitive decline due to neurodegenerative diseases such as AD as well as for confirming the therapeutic effect of alcoholic cognitive decline.[10]

As with the studies described above, many researchers have paid attention to the MoCA index scores. To the best of our knowledge, however, no research has investigated the validity of MoCA index scores in comparison with conventional neuropsychological tests. The present study was conducted to investigate whether the MoCA index scores represent each cognitive function by examining the correlations with corresponding cognitive domain scores derived from conventional neuropsychological tests.

METHODS

Participants

The participants were 104 with aMCI, 74 with vascular MCI (VaMCI), 73 with dementia of the Alzheimer's type (DAT), and 41 with vascular dementia (VaD) patients who visited the Department of Neurology, Hallym University Sacred Heart Hospital. All patients underwent a clinical interview with a neurologist, neurological examination, brain imaging, and neuropsychological tests. The neurologists made a diagnosis based on the above information. The Petersen's criteria were used for aMCI.[11] The clinical diagnosis of DAT was based on the criteria of the National Institute on Aging-Alzheimer's Association (NIA-AA) workgroup.[12] The VaMCI and VaD diagnoses were based on the criteria for probable VaMCI and VaD of the American Heart Association-American Stroke Association (AHA/ASA).[13]

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Measures

Each participant underwent a clinical evaluation that included a medical history taking, screening of depression (Short form of the Geriatric Depression Scale; SGDS),[14] Clinical Dementia Rating (CDR),[15] and a comprehensive neuropsychological battery (Seoul Neuropsychological Screening Battery, 2nd Edition; SNSB-II),[16] including the Korean-MoCA (K-MoCA)[2] and Korean-Mini Mental State Examination (K-MMSE).[17] Tests were administered in the order of K-MoCA, SNSB-II, SGDS, K-MMSE, and CDR.

Following Julayanont et al.,[6] we scored 6 index scores of K-MoCA: (1) Orientation Index Score (OIS): sum of points for the orientation section of K-MoCA, with a score ranging from 0 to 6; (2) Attention Index Score (AIS): digit span forward and backward, letter A tapping (it was substituted "Monday" tapping in K-MoCA), serial-7 subtraction, sentence repetition, and words recalled in both immediate recall trials, with a score ranging from 0 to 18; (3) Language Index Score (LIS): naming, sentence repetition, and letter fluency, with a score ranging from of 0 to 6; (4) Visuospatial Index Score (VIS): cube copy, clock drawing, and naming, with a score range from 0 to 7; (5) Memory Index Score (MIS): the number of words remembered in free delayed recall, category-cued recall, and multiple choice-cued recall multiplied by 3, 2, and 1, respectively, with a score ranging from 0 to 15; (6) Executive Index Score (EIS): modified Trail-Making Test Part B, clock drawing, digit span forward and backward, letter A tapping, serial-7 subtraction, letter fluency, and abstraction, with a score ranging from 0 to 13.

The SNSB-II consisted of 5 cognitive domains giving 5 cognitive domain scores like the MoCA, except for the OIS. The subtests that made up each cognitive domain score were as follows: (1) Attention (SNSB-A): Digit Span Test (forward, backward); (2) Language (SNSB-L): comprehension, repetition, and Korean-Boston Naming Test; (3) Visuospatial function (SNSB-V): Rey Complex Figure Test-copy and Clock Drawing Test; (4) Memory (SNSB-M): Seoul Verbal Learning Test and Rey Complex Figure Test; and (5) Frontal/executive function (SNSB-F): go/no-go, phonemic fluency, Korean-Color Word Stroop Test-color reading, Digit Symbol Coding, and Korean-Trail Making Test-Elderly's version Part B (**Table 1**). The cognitive domain score was a composite of the standardized scores of the subtests that made up each cognitive domain.

Statistical analysis

Data analysis was conducted using analyses of variance (ANOVA) and Pearson's χ^2 test for examining the diagnostic group differences between demographic variables (age, sex, and education) and other measures (depression level, K-MMSE, and CDR). Significant results of ANOVA were followed by *post hoc* comparisons using Tukey's test.

Table 1. Subtests of MoCA index score and SNSB cognitive domain score

Cognitive domain	MoCA index score	SNSB cognitive domain score
Orientation	orientation	-
Attention	digit span forward & backward, letter A tapping, serial-7 subtraction, sentence repetition, words recalled in both immediate recall trials	Digit Span Test (forward & backward)
Language	naming, sentence repetition, letter fluency	comprehension, repetition, K-BNT
Visuospatial function	cube copy, clock drawing, naming	RCFT copy, clock drawing test
Memory	number of words recalled in free recall, delayed recall, category-cued recall, & multiple choice-cued recall multiplied by 3, 2, and 1, respectively	SVLT (immediate recall, delayed recall, & recognition), RCFT (immediate recall, delayed recall, & recognition)
Executive function	modified Trail-Making Test Part B, clock drawing, digit span forward & backward, letter A tapping, serial-7 subtraction, letter fluency, abstraction	go/no-go, COWAT: Phonemic, K-CWST: color reading, Digit Symbol Coding, K-TMT-E: Part B

K-BNT: Korean-Boston Naming Test, RCFT: Rey Complex Figure Test, SVLT: Seoul Verbal Learning Test, COWAT: Controlled Oral Word Association Test, K-CWST: Korean Color Word Stroop Test, K-TMT-E: Korean-Trail Making Test-Elderly's version.

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Analysis of covariance (ANCOVA) and multivariate ANCOVA (MANCOVA) were used to compare the MoCA total score and the MoCA index scores, respectively, to differentiate between diagnostic groups (aMCI, VaMCI, DAT, and VaD). We also performed Bonferroni *post hoc* analyses. Correlation analyses were conducted to explore relationships between the 5 K-MoCA index scores, except the OIS, which was not the domain included in the SNSB-II, and 5 SNSB-II cognitive domain scores calculated in the scoring program. We used IBM SPSS Statistics (version 27.0; IBM Corp., Armonk, NY, USA) to perform all analyses.

Ethics statement

The study protocol was reviewed and approved by the Institutional Review Board (IRB) of Hallym University Sacred Heart Hospital (IRB No. 2019-03-011-001).

RESULTS

Table 2 summarizes the demographic data, SGDS, K-MMSE, and CDR of participants. DAT patients were older than MCI groups, and other groups did not have differences. Sex composition was significantly different between the groups. There were no differences in education and depression levels of the groups. The K-MMSE scores did not differ between either MCI groups (aMCI vs. VaMCI) or dementia groups (DAT vs. VaD). However, MCI groups scored higher than dementia groups. The dementia groups scored higher CDR than MCI groups, but there was no difference between either MCI groups (aMCI vs. VaMCI) or dementia groups (DAT vs. VaD).

Tables 3 and **4** show the MoCA and SNSB-II performances of the groups, respectively (see the details in **Supplementary Table 1**). ANCOVA controlling for age and sex revealed significant differences among the MoCA total scores of the groups (F=22.03, p<0.001, partial η^2=0.19; **Table 3**). MCI groups scored higher than dementia groups. However, there were no differences between either MCI groups or dementia groups. MANCOVA was conducted for 6 index scores (λ=0.61, F=8.54, p<0.001, partial η^2=0.15). Univariate tests for each index score were performed (MoCA-OIS, F=45.53, p<0.001, partial η^2=0.32; MoCA-AIS, F=10.94, p<0.001, partial η^2=0.10; MoCA-LIS F=6.22, p<0.001, partial η^2=0.06; MoCA-VIS, F=7.72, p<0.001, partial η^2=0.08; MoCA-MIS F=11.96, p<0.001, partial η^2=0.11; MoCA-EIS F=10.89, p<0.001, partial η^2=0.10; **Table 4**). Dementia groups scored lower than MCI groups on the MoCA-OIS. The difference was not significant between aMCI and VaMCI groups, and the DAT and VaD groups, respectively. The VaD group scored significantly lower than the other three groups on MoCA-AIS and MoCA-EIS. However, there were no differences among the aMCI, VaMCI,

Table 2. Demographical characteristics, SGDS, K-MMSE, and CDR of the participants

Characteristics	aMCI[a] (n=104)	VaMCI[b] (n=74)	DAT[c] (n=73)	VaD[d] (n=41)	F or χ^2	*Post hoc* (Tukey)
Age (yr)	73.72±8.69	73.69±7.83	78.96±11.03	77.63±5.97	6.98***	a=b<c, c=d, a=b=d
Sex (M/F)	36/68	39/35	23/50	19/22	χ^2=9.11*	-
Education (yr)	8.63±4.50	8.14±4.69	7.93±4.58	8.63±5.25	9.02	-
SGDS	4.98±4.37	5.24±4.02	4.89±4.22	6.27±4.37	1.14	-
K-MMSE	24.65±3.05	25.15±2.90	21.08±3.49	20.76±4.18	32.57***	a=b>c=d
CDR-GS	0.50±0.00	0.49±0.10	1.03±0.33	1.09±0.37	148.97***	a=b<c=d
CDR-SB	1.76±1.03	1.72±1.06	5.71±1.82	5.85±2.19	174.05***	a=b<c=d

Values are presented as mean±standard deviation.
SGDS: Short form of the Geriatric Depression Scale, K-MMSE: Korean-Mini Mental State Examination, CDR: Clinical Dementia Rating, aMCI: amnestic mild cognitive impairment, VaMCI: vascular mild cognitive impairment, DAT: dementia of Alzheimer's Type, VaD: vascular dementia, CDR-GS: Clinical Dementia Rating-Global Score, CDR-SB: Clinical Dementia Rating-Sum of Boxes.
*p<0.05, ***p<0.001.

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Table 3. Group differences in the MoCA total score and MoCA index scores

MoCA index	aMCI[a] (n=104)	VaMCI[b] (n=74)	DAT[c] (n=73)	VaD[d] (n=41)	*F*	*Post hoc* (Bonferroni)
MoCA-OIS	5.13±1.20	5.50±.82	3.22±1.51	3.66±1.58	45.53***	a=b>c=d
MoCA-AIS	13.47±2.73	13.81±2.97	12.10±3.40	10.44±3.12	10.94***	a=b=c>d
MoCA-LIS	4.63±1.27	4.77±1.31	4.05±1.44	3.59±1.57	6.22***	a=b>d, a=b=c, c=d
MoCA-VIS	5.42±1.60	5.42±1.66	4.47±1.73	4.05±1.66	7.72***	a>c=d, b=c, a=b>d
MoCA-MIS	4.62±3.30	5.61±3.80	2.42±1.86	2.76±2.97	11.96***	a=b>c, a=d, b>c=d
MoCA-EIS	8.47±3.00	8.50±2.85	6.88±2.87	5.61±2.67	10.89***	a=b=c>d
MoCA-Total	18.66±4.99	19.49±4.62	14.10±4.75	13.07±4.83	22.03***	a=b>c=d

Values are presented as mean±standard deviation.
MoCA: Montreal Cognitive Assessment, aMCI: amnestic mild cognitive impairment, VaMCI: vascular mild cognitive impairment, DAT: dementia of Alzheimer's type, VaD: vascular dementia, MoCA-AIS: Montreal Cognitive Assessment-Attention Index Score, MoCA-LIS: Montreal Cognitive Assessment-Language Index Score, MoCA-VIS: Montreal Cognitive Assessment-Visuospatial Index Score, MoCA-MIS: Montreal Cognitive Assessment-Memory Index Score, MoCA-EIS: Montreal Cognitive Assessment-Executive function Index Score.

Table 4. Group differences in the SNSB-II domain scores

Cognitive domain	aMCI[a] (n=104)	VaMCI[b] (n=74)	DAT[c] (n=73)	VaD[d] (n=41)	*F*	*Post hoc* (Bonferroni)
SNSB-A	8.60±2.03	8.35±1.78	8.18±1.88	7.49±1.66	0.02*	a=b=c, a>d, b=c=d
SNSB-L	−0.15±0.46	−0.01±0.36	−0.35±0.35	−0.55±0.61	12.41***	a=b>d, a=c>d, b>c
SNSB-V	−0.24±0.77	−0.47±0.77	−0.80±0.83	−1.10±0.83	11.40***	a=b>d, b=c, a>c=d
SNSB-M	−0.88±0.68	−0.66±0.69	−1.78±0.48	−1.46±0.55	40.96***	a=b>c=d
SNSB-E	−0.58±0.83	−0.65±0.83	−1.15±0.79	−1.66±0.66	18.60***	a=b>d, a>c, b=c>d

SNSB-II: Seoul Neuropsychological Screening Battery, 2nd Edition, aMCI: amnestic mild cognitive impairment, VaMCI: vascular mild cognitive impairment, DAT: dementia of Alzheimer's type, VaD: vascular dementia, SNSB-A: Seoul Neuropsychological Screening Battery-Attention, SNSB-L: Seoul Neuropsychological Screening Battery-Language, SNSB-V: Seoul Neuropsychological Screening Battery-Visuospatial function, SNSB-M: Seoul Neuropsychological Screening Battery-Memory, SNSB-F: Seoul Neuropsychological Screening Battery-Frontal/executive function.
*p<0.05, ***p<0.001.

and DAT groups. On the MoCA-LIS, MCI groups showed a significantly higher score than the VaD group, but there was no difference among the aMCI, VaMCI, and DAT groups, as well as between DAT and VaD groups. On the MoCA-VIS, the aMCI group scored higher than the dementia groups. However, the VaMCI group showed no difference with DAT group. The VaD group scored significantly lower than MCI groups. On the MoCA-MIS, both MCI groups scored higher than the DAT group. The VaMCI group scored significantly higher than the VaD group, although there was no difference between the aMCI and VaD groups.

Table 5 presents correlations between K-MoCA index scores, excluding MoCA-OIS, which was not provided in the SNSB-II, and SNSB-II cognitive domain scores. In the aMCI group, all index scores of the K-MoCA showed moderate-to-high correlations with the corresponding cognitive domain scores of the SNSB-II (MoCA-AIS r=0.61, p<0.001; MoCA-LIS r=0.75, p<0.001; MoCA-VIS r=0.83, p<0.001; MoCA-MIS r=0.55, p<0.001; MoCA-EIS r=0.70, p<0.001). In the VaMCI group, as with the aMCI group, all K-MoCA index scores showed moderate-to-high correlations with the corresponding cognitive domain scores of the SNSB-II (MoCA-AIS r=0.65, p<0.001; MoCA-LIS r=0.65, p<0.001; MoCA-VIS r=0.85, p<0.001; MoCA-MIS r=0.53, p<0.001; MoCA-EIS r=0.75, p<0.001). In the DAT group, the MoCA-AIS, MoCA-LIS, MoCA-VIS, and MoCA-EIS showed moderate-to-high correlations with the corresponding domain scores of the SNSB-II (MoCA-AIS r=0.51, p<0.001; MoCA-LIS r=0.64, p<0.001; MoCA-VIS r=0.79, p<0.001; MoCA-EIS r=0.76, p<0.001). However, there was no correlation between the MoCA-MIS and the memory domain score of SNSB-II (r=0.22, p=ns). In the VaD group, as with the DAT group, the MoCA-AIS (r=0.62, p<0.01), MoCA-LIS (r=0.69, p<0.01), MoCA-VIS (r=0.67, p<0.01), and MoCA-EIS (r=0.59, p<0.01) significantly correlated to the corresponding cognitive domain scores of the SNSB-II. However, the MoCA-MIS did not significantly correlate with memory domain score of the SNSB-II.

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Table 5. Correlations between the K-MoCA Index Scores and SNSB-II Cognitive Domain Scores for aMCI, VaMCI, DAT, and VaD groups

Group & MoCA index	SNSB cognitive domain				
	SNSB-A	SNSB-L	SNSB-V	SNSB-M	SNSB-F
aMCI					
MoCA-AIS	0.61***	0.52***	0.55***	0.39***	0.56***
MoCA-LIS	0.54**	0.75***	0.57***	0.40***	0.56***
MoCA-VIS	0.54**	0.70***	0.83***	0.37***	0.56***
MoCA-MIS	0.24*	0.26***	0.22*	0.55***	0.39***
MoCA-EIS	0.67***	0.62***	0.78***	0.41***	0.70***
VaMCI					
MoCA-AIS	0.65***	0.64***	0.58***	0.45***	0.60***
MoCA-LIS	0.54***	0.65***	0.44***	0.29*	0.54***
MoCA-VIS	0.52***	0.62***	0.85***	0.32**	0.60***
MoCA-MIS	0.32**	0.37**	0.30**	0.53***	0.48***
MoCA-EIS	0.62***	0.65***	0.71***	0.47***	0.75***
DAT					
MoCA-AIS	0.51***	0.41***	0.46***	0.27*	0.57***
MoCA-LIS	0.40***	0.64***	0.57***	0.32**	0.51***
MoCA-VIS	0.34***	0.60***	0.79***	0.23	0.52***
MoCA-MIS	−0.02	0.16	0.13	0.22	0.33*
MoCA-EIS	0.60***	0.62***	0.66***	0.25*	0.76***
VaD					
MoCA-AIS	0.62***	0.65***	0.51**	0.41**	0.51**
MoCA-LIS	0.55***	0.69***	0.47**	0.38*	0.46**
MoCA-VIS	0.60***	0.60***	0.67***	0.22	0.44**
MoCA-MIS	0.35*	0.32*	0.27	0.24	0.48**
MoCA-EIS	0.69***	0.57***	0.70***	0.23	0.59***

K-MoCA: Korean-Montreal Cognitive Assessment, SNSB-II: Seoul Neuropsychological Screening Battery, 2nd Edition, aMCI: amnestic mild cognitive impairment, VaMCI: vascular mild cognitive impairment, DAT: dementia of the Alzheimer's type, VaD: vascular dementia, MoCA-AIS: Montreal Cognitive Assessment-Attention Index Score, MoCA-LIS: Montreal Cognitive Assessment-Language Index Score, MoCA-VIS: Montreal Cognitive Assessment-Visuospatial Index Score, MoCA-MIS: Montreal Cognitive Assessment-Memory Index Score, MoCA-EIS: Montreal Cognitive Assessment-Executive function Index Score, SNSB-A: Seoul Neuropsychological Screening Battery-Attention, SNSB-L: Seoul Neuropsychological Screening Battery-Language, SNSB-V: Seoul Neuropsychological Screening Battery-Visuospatial function, SNSB-M: Seoul Neuropsychological Screening Battery-Memory, SNSB-F: Seoul Neuropsychological Screening Battery-Frontal/executive function.
*p<0.05, **p<0.01, ***p<0.001.

DISCUSSION

For examining the validity of the MoCA index scores, we investigated the differences among the MCI and dementia groups in MoCA index scores, and compared the MoCA index scores with cognitive domain scores from the SNSB-II, a comprehensive neuropsychological test battery comprising a variety of conventional neuropsychological tests.

In the sum of group differences in the MoCA index scores, MoCA-OIS, like the MoCA total score, showed the differences between MCI and dementia groups in both AD and vascular cognitive impairment (VCI). The MoCA-AIS, MoCA-LIS, and MoCA-EIS showed significant differences between VaMCI and VaD, but aMCI and DAT showed no difference between each other. These findings indicate impaired attention, language, and executive functions from the early stages of AD, as reported in previous studies.[18,19] Several studies have reported that aMCI showed deficits in attention and executive function on neuropsychological tests.[20,21] It was also found that the brain's network functions, related to attention and executive function, had already changed in aMCI group.[22,23] A number of studies have shown that language impairment, including naming difficulty, appears in early MCI.[24,25] Like in the MoCA-OIS, there were significant differences not only between aMCI and DAT but also between VaMCI and VaD in MoCA-VIS and MoCA-MIS. In particular, unlike the VaMCI, aMCI did not differ from VaD in MoCA-MIS, indicating that the memory of aMCI declined as much

as VaD. In MoCA-VIS, VaMCI did not differ from DAT, indicating that the visuoconstuctive function of VaMCI declined as much as DAT. These results showed that the MoCA index scores revealed the characteristics of cognitive dysfunction at MCI and dementia levels of AD and VCI found in previous studies.[26,27] Therefore, the MoCA index scores may provide clues to differential diagnosis between aMCI and VaMCI. Our results also indicate that the MoCA index scores may be particularly useful for VCI as the differences between VaMCI and VaD were significant for all 6 index scores as well as the total score.

For both aMCI and VaMCI, all MoCA index scores were highly correlated with the corresponding cognitive domain scores of the SNSB-II. These results suggest that the MoCA index scores could provide valid information about each cognitive domain like conventional neuropsychological tests. For the dementia groups, however, the MoCA-MIS was not significantly correlated with the SNSB-M, while all other index scores were highly correlated with the corresponding cognitive domain scores of SNSB-II. This indicates that the MoCA-MIS is limited in reflecting the degree of memory impairment in dementia groups. Although the ceiling effect of the MoCA subtests has already been mentioned in previous studies,[28] the limitations of the MoCA-MIS found in the present study are considered to represent the floor effect of memory subtests in the MoCA. While the Seoul Verbal Learning Test (SVLT), a verbal memory test included in the SNSB-II, used a list of 12 words, the MoCA used a shorter list of 5 words. It seemed that the floor effect appeared in dementia patients due to small number of words, and unlike the SVLT, we did not observe the performance difference according to the degree of dementia in the MoCA. This would have lowered the correlation between the MoCA-MIS and SNSB-M. As a post-hoc analysis, we re-analyzed the data for the overall MCI (n=178) and dementia (n=114) groups instead of subgrouping them. Consequently, a small but significant correlation (t=24, p<0.05) was found between MoCA-MIS and SNSB-M (**Table 6**). However, it was the weakest correlation compared to other MoCA index scores. These results suggest that we should exercise caution while assessing memory in dementia patients with MoCA-MIS, and supplement it with other memory tests.

To the best of our knowledge, this is the first study to examine the validity of the MoCA index scores in VaMCI and VaD groups as well as aMCI and DAT groups, and compare them with cognitive domain scores derived from a variety of conventional neuropsychological tests. The results of the study confirmed that the MoCA index scores were valid measures that reflected the cognitive characteristics and level of cognitive deterioration in aMCI, DAT, and VCI groups. We concluded that the MoCA index scores sufficiently represent the functions of each cognitive domain; they showed high and significant correlations with the conventional

Table 6. Correlations between the K-MoCA Index Scores and SNSB-II Cognitive Domain Scores for dementia patients

	SNSB cognitive domain				
MoCA index	SNSB-A	SNSB-L	SNSB-V	SNSB-M	SNSB-F
MoCA-AIS	0.56***	0.52***	0.50***	0.23*	0.58***
MoCA-LIS	0.46***	0.66***	0.55***	0.28**	0.50***
MoCA-VIS	0.44***	0.58***	0.75***	0.18	0.50***
MoCA-MIS	0.12	0.24*	0.17	0.24*	0.33***
MoCA-EIS	0.64***	0.54***	0.68***	0.17	0.73***

K-MoCA: Korean-Montreal Cognitive Assessment, SNSB-II: Seoul Neuropsychological Screening Battery, 2nd Edition, MoCA-AIS: Montreal Cognitive Assessment-Attention Index Score, MoCA-LIS: Montreal Cognitive Assessment-Language Index Score, MoCA-VIS: Montreal Cognitive Assessment-Visuospatial Index Score, MoCA-MIS: Montreal Cognitive Assessment-Memory Index Score, MoCA-EIS: Montreal Cognitive Assessment-Executive function Index Score, SNSB-A: Seoul Neuropsychological Screening Battery-Attention, SNSB-L: Seoul Neuropsychological Screening Battery-Language, SNSB-V: Seoul Neuropsychological Screening Battery-Visuospatial function, SNSB-M: Seoul Neuropsychological Screening Battery-Memory, SNSB-F: Seoul Neuropsychological Screening Battery-Frontal/executive function.
*p<0.05, **p<0.01, ***p<0.001.

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neuropsychological tests evaluating the corresponding cognitive domains in both MCI and dementia groups, except for MoCA-MIS in the dementia groups.

This study has some limitations. Even though neurologists based their diagnosis for this study on a clinical interview, neurological examination, brain imaging, and neuropsychological tests, we could not get sufficient data about pathological information (e.g., amyloid-β or tau proteins) and imaging diagnosis (e.g., stroke lesion) for all participants. Therefore, there is a possibility that some patients with mixed pathology were included in the MCI and dementia subgroups. We expect that this study will be replicated with more well-defined patients in the future.

There are many situations when a rigorously trained neuropsychologist is not available or comprehensive neuropsychological assessments are difficult to conduct. The MoCA could be an alternative in such a setting. To date, the MoCA has been used as a cognitive screening test using only the total score. The newly developed MoCA index scores can provide detailed information on specific cognitive domains in a lesser time. This study provides instructive guidelines for using MoCA index scores. To increase their resourcefulness in clinical settings, future studies should develop standardized norms for MoCA index scores.

SUPPLEMENTARY MATERIAL

Supplementary Table 1

Group differences in the MoCA total score and MoCA index scores

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