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Review Article

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The Seoul Neuropsychological Screening Battery (SNSB) for Comprehensive Neuropsychological Assessment

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ABSTRACT

The Seoul Neuropsychological Screening Battery (SNSB) is known as a representative comprehensive neuropsychological evaluation tool in Korea since its first standardization in 2003. It was the main neuropsychological evaluation tool in the Clinical Research Center for Dementia of South Korea, a large-scale multi-center cohort study in Korea that was started in 2005. Since then, it has been widely used by dementia clinicians, and further solidified its status as a representative dementia evaluation tool in Korea. Many research results related to the SNSB have been used as a basis for the diagnosis and evaluation of patients in various clinical settings, especially, in many areas of cognitive assessment, including dementia evaluation. The SNSB version that was updated in 2012 provides psychometrically improved norms and indicators through a model-based standardization procedure based on a theoretical probability distribution in the norm's development. By providing a score for each cognitive domain, it is easier to compare cognitive abilities between domains and to identify changes in cognitive domain functions over time. Through the development of the SNSB-Core, a short form composed of core tests, which also give a composite score was provided. The SNSB is a useful test battery that provides key information on the evaluation of early cognitive decline, analysis of cognitive decline patterns, judging the severity of dementia, and differential diagnosis of dementia. This review will provide a broad understanding of the SNSB by describing the test composition, contents of individual subtests, characteristics of standardization, analysis of the changed standard score, and related studies.

Keywords: Seoul Neuropsychological Screening Battery; Neuropsychological Tests; Cognition; Dementia

INTRODUCTION

The Seoul Neuropsychological Screening Battery (SNSB)[1] was developed in 2003 by neurologist Duk Lyul Na, M.D. and neuropsychologist Yeonwook Kang, Ph.D., who had been treating dementia patients at the Department of Neurology, Samsung Medical Center, Sungkyunkwan University School of Medicine. At the time when the SNSB was developed, Korea desperately needed a standardized neuropsychological evaluation tool that could comprehensively assess various cognitive functions for dementia evaluation.

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The development of the SNSB provided an opportunity for qualitative improvement in the implementation and evaluation of neuropsychological tests for dementia diagnosis in Korea. Notably, Clinical Research Center for Dementia of South Korea (CREDOS)[2] is the driving force for the establishment of the SNSB as a representative comprehensive neuropsychological evaluation tool in Korea. The CREDOS study was a multi-center cohort study carried out in dementia clinics in 56 clinical centers in Korea. The study targeted more than 3,000 subjects for 7 years, starting from 2005, to evaluate the long-term effects of dementia in Korean patients. The SNSB was the main neuropsychological assessment tool in the CREDOS study, this led to the recognition of SNSB by dementia clinical experts as a representative comprehensive neuropsychological assessment tool in Korea. Currently, 3 comprehensive neuropsychological evaluation tools for dementia diagnosis are supported by government insurance. According to the Health Insurance Review and Assessment Service data, the SNSB accounted for about two-thirds of usage as of 2021 (the SNSB: 65%, the Korean version of the Consortium to Establish a Registry for Alzheimer's Disease (AD)[3]: 24%, the Literacy Independent Cognitive Assessment (LICA)[4]: 11%). The SNSB is more common in relatively large-scale hospitals than in small ones, and almost all dementia clinics in the neurology department of the largest hospitals in Korea use the SNSB as a dementia evaluation tool. The SNSB updated the normative data in 2012 to reflect the changed generational characteristics. Compared to the original SNSB, the 2nd edition of the SNSB (SNSB-II)[5] broadened the age range and educational level, and expanded its tests to assess different aspects of cognitive function. In particular, it adopted a model-based norming method to provide improved normative data. The SNSB-II additionally provides cognitive domain scores, the brief version of the SNSB (SNSB-Core [SNSB-C])[6] consisting of core tests representing cognitive domains, and a composite score derived from the SNSB-C.

In this review, the overall contents of the SNSB-II will be described by first summarizing the test composition and standardization of the SNSB-II. Next, the effect of norm update will be examined by comparing means of the same norm subgroups between the original SNSB and the SNSB-II. Finally, by analyzing various papers using the SNSB, the clinical usefulness of the SNSB will be described.

COMPOSITION OF THE SNSB-II

The SNSB-II consists of 3 categories: basic information, cognitive function tests, and other indexes. To determine the specific normative data to be compared for evaluating a patient's cognitive function and to increase the reliability of the evaluation, it is necessary to check basic information such as the patient's age, sex, educational background, and occupation. It also includes a handedness test, which can be used as an important clue to functional brain asymmetry. Other indexes include several tests needed for dementia assessment that are not included in objective cognitive function tests: the Clinical Dementia Rating (CDR),[7] Global Deterioration Scale,[8] Short Version of the Geriatric Depression Scale (SGDS),[9] Barthel-Activities of Daily Living,[10] and Korean-Instrumental Activities of Daily Living.[11] The time required to perform the entire SNSB-II is approximately 1 hour 45 minutes to 2 hours, and if only cognitive function tests are performed, it takes approximately 1 hour to 1 hour 15 minutes.

Cognitive function tests consist of a total of 29 subtests, and can be divided into 5 cognitive domains: attention, language & related functions, visuospatial functions, memory, and frontal/executive functions (**Table 1**). The 15 subtests are evaluated quantitatively. Among them, the auditory comprehension test produces a qualitative result simultaneously.

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The attention domain is composed of 2 auditory tests (the vigilance test and the Digit Span Test [DST]) and one visual test (the letter cancellation). The vigilance test, which evaluates the subject's level of arousal, is performed first. Because the test is simple, it helps to reduce the subject's test anxiety while keeping them interested in subsequent cognitive tasks. The DST measures an individual's attention/concentration along with working memory by measuring forward and backward immediate recall (IR) spans. The letter cancellation test measures basic selective visual attention. It also makes it possible to screen for hemispatial neglect, such as spatial neglect syndromes. Among the language & related functions domain, language

Table 1. Composition of the SNSB-II

Domain/Subtest (score)	Description
Attention	
[1] Vigilance test (N, B, Ab)	The examiner reads out the subject randomly mixed days of the week at 2-sec intervals. When a specific day of the week (Monday) is heard, the subject must clap once.
[2-1] DST:F (0, 3–9)	The examiner reads out the subject a sequence of numbers. The test starts with 3-digit numbers, and the maximum sequence length is 9. The subject must say the numbers in the order they are heard. If the first trial of the same span is successful, it advances to the next digit span. If both the first and second trials of the same span fail, the test is stopped.
[2-2] DST:B (0, 2–8)	The test starts with 2-digit numbers, and the maximum sequence length is 8. The subject must say the numbers in reverse order. Everything else is the same as the DST:F.
[3] Letter cancellation (N, B, Ab; Left, Right)	Forty-eight Korean consonants of 7 types are randomly arranged on a A4 horizontal paper. The subject must circle only the 10 target consonants (/g/).
Language & related functions	
[4] Spontaneous speech (Fluent, Non-fluent; N, B, Ab)	Throughout the test, the subject's verbal fluency and the adequacy of the content are monitored and evaluated.
[5] Comprehension (N, B, Ab; 0–5)	The subject is asked 5 simple yes or no answerable questions.
[6] Repetition (0–15)	The test consists of a total of 5 items, starting with one Korean word and ending with 5 Korean spacing units. The examiner reads out each item one by one, and the subject must repeat it.
[7-1] K-BNT (0–60)	It consists of 60 black and white line drawings. The subject should look at the picture presented and say its name.
[7-2] S-K-BNT (0–15)	It consists of 15 black and white line drawings. This test is one of the isoform short-form tests of K-BNT. The subject should look at the picture presented and say its name.
[8] Reading (N, B, Ab)	The subject must read out one simple sentence on its own and act on that sentence.
[9] Writing (N, B, Ab)	The subject must voluntarily write down one random sentence on paper.
[10] Finger naming (N, B, Ab)	The examiner shows the subject the thumb, little finger, and middle finger in turn. The subject must say the name of the finger shown.
[11] Right-left orientation (N, B, Ab)	The examiner asks the subject to do 3 things: showing the subject's left hand, pointing to the examiner's right hand, and placing the subject's right hand on top of the examiner's left hand.
[12] Body-part identification (N, B, Ab)	The examiner asks the subject to point to their body parts: wrist, elbow, knee, and shoulder.
[13] Calculation (0–12)	Addition, subtraction, multiplication, and division are evaluated for a total of 12 questions, 3 each.
[14] Praxis:buccofacial (N, B, Ab)	The examiner asks the subject to demonstrate the following actions as if they were performed: whistling, sucking a drink with a straw, blowing out candles, and smelling food.
[15] Praxis:ideomotor (0–5)	The examiner asks the subject to demonstrate the following actions as if using a real tool: hammering, screwing with a screwdriver, scissoring, opening the door with a key, and slicing cooked rice rolled in dried sheets of seaweed with a knife.
Visuospatial functions	
[16-1] RCFT:copy (0–36; 0–600 sec)	The test uses the Rey complex figure devised by Andre Rey in 1941. The time limit for copying is 10 min. The scoring is calculated by dividing the whole into 18 elements, with 2 points for each element.
[17] CDT (0–3)	The subject is asked to draw a clock with hour and minute hands corresponding to 11:10 on paper. The scoring evaluates 3 factors: contour, numbers, and time setting.
Memory	
[18-1] SVLT-E:IR (0–36)	The word list in the test consists of 12 items divided into 3 categories (flowers, housekeeping tools, school supplies), and each category contains 4 words. After the examiner reads out all 12 words to the subject, the examiner asks the subject to recall the words again. The test performs a total of 3 times.
[18-2] SVLT-E:DR (0–12)	The test is done about 20 min after the SVLT-E:IR. The examiner asks the subjects to recall the words learned in the SVLT-E:IR without clues.
[18-3] SVLT-E:recognition (0–24)	The test is done right after the SVLT-E:DR. The examiner reads out 24 words (12 target words and 12 non-target words) one by one and asks the subject to judge whether the word is included in the SVLT-E:IR or not. The score is True Positive+(12−False Positive).
[16-2] RCFT:IR (0–36)	The test is done right after the RCFT:copy. The scoring is the same as the RCFT:copy scoring method.
[16-3] RCFT:DR (0–36)	The test is done about 20 min after the RCFT:DR. The scoring is the same as the RCFT:copy scoring method.
[16-4] RCFT:recognition (0–24)	The test is done right after the RCFT:DR. The examiner shows 24 figure fragments (12 target fragments and 12 non-target fragments) and asks the subjects to judge whether the figure piece is part of the RCFT:copy or not. The score is True Positive+(12−False Positive).

(continued to the next page)

functions include tests of spontaneous speech, comprehension, repetition, confrontation naming (the Korean-Boston Naming Test [K-BNT] and the Short Form of the K-BNT [S-K-BNT]), reading, and writing. These 6 parts are essential for the evaluation of basic language function. The spontaneous speech test assesses the adequacy of 2 aspects of verbal expression (fluency and content). The S-K-BNT (15 items) is a shortened test with the same efficiency as the K-BNT (60 items). The related functions include tests for Gerstmann's syndrome screening (finger naming, right-left orientation, body-part identification, and calculation) and tests for buccofacial and limb apraxia screening. The visuospatial function's domain consists of the Rey Complex Figure Test (RCFT):copy and the Clock Drawing Test (CDT). In the RCFT:copy, each z-score is provided to judge the accuracy of visuospatial construction (36 points in total) and the appropriateness of the execution time (up to 10 minutes).

The memory domain is composed of 2 main parts: the Seoul Verbal Learning Test-Elderly's version (SVLT-E):IR, delayed recall (DR), and recognition, which evaluates verbal memory, and the RCFT:IR, DR, and recognition, which evaluates visual memory. For the SVLT-E:recognition and the RCFT:recognition, the following recognition discriminability index is additionally provided.

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SIVD group showed frontal/executive dysfunction (the COWAT and the K-CWST:CR) and visuoconstructional impairment (the RCFT:copy). On the other hand, the AD group showed verbal memory deficits (the SVLT-E:DR/recognition) compared to the SIVD group. In particular, these results related to executive functions and memory were observed in both AD patients with and without small vessel disease. Similar results were found in another study using the SNSB to compare AD and subcortical vascular dementia (SCVD).[18] In the study, the SCVD group showed a significant decrease in the COWAT:phonemic compared to the AD group, whereas the AD group had a significantly decreased performance in the SVLT-E:DR/recognition compared to the SCVD group.

Meanwhile, Kang et al.[19] compared cognitive evaluation results between AD and mixed dementia (a combination of AD and vascular pathology) according to the severity of dementia. In the CDR 0.5 group, the frontal/executive domain score of mixed dementia patients was significantly lower than that of AD, and there was no significant difference in the memory performance. On the other hand, in the CDR 1 group, the AD group showed significantly lower performance in the memory domain, and there was no significant difference in the frontal/executive domain. At the CDR 2 stage, the differences between groups disappeared, indicating that the severity of dementia should be considered when distinguishing AD and mixed dementia groups by cognitive profile. In a study comparing the cognitive characteristics of the Dementia with Lewy Bodies (DLB) group with AD and Parkinson's disease dementia groups through the SNSB, the DLB group showed significantly lower performance in the DST:B than the other 2 groups.[20] Regarding the SVLT-E:DR, it was reported that the performance of the DLB group was significantly lower than that of the Parkinson's disease dementia group, but there was no significant difference with AD. There is a study comparing the SNSB performance between svMCI and Parkinson's disease and mild cognitive impairment (PD-MCI). The svMCI group had a significantly better performance in the SVLT-E:recognition than the PD-MCI group.[18] On the other hand, svMCI showed a significant decrease in performance in the COWAT:phonemic, RCFT:copy, and RCFT:IR/DR compared to PD-MCI.

Neural correlates of SNSB subtests

The relationship between cognitive dysfunction and the neuro-anatomical lesion has long been a hot topic in the neuroscience field. Ahn et al.[21] analyzed the relationship between cortical thickness and subtests of the original SNSB using magnetic resonance imaging surface-based morphometry for aMCI and AD. In the study, test-specific brain areas were identified in most subtests except for the DST:F, SVLT-E:recognition, RCFT:recognition, and K-CWST:WR. Regarding the laterality of neural correlates of neuropsychological deficits, the decline in the DST:B and the COWAT:phonemic showed a strong correlation with left hemisphere atrophy, and the poor performance in the RCFT:copy/IR/DR showed a strong correlation with right hemisphere atrophy. Regarding the SNSB-II, Kang et al.[22] analyzed the relationship between neuropsychological tests and cortical thickness in Alzheimer's continuum (a comprehensive of preclinical AD, MCI due to AD, and AD dementia) with positive amyloid deposits. In most subtests excluding the DST:F, RCFT:recognition, and K-TMT-E:part-B, correlations between cortical thinning in specific brain regions and neuropsychological test performance were confirmed. Subtests showing strong left hemispheric dominance were DST:B and COWAT:semantic (animal). The COWAT:phonemic showed strong right hemispheric dominance in the study, which is contrary to the study of Ahn et al.[21] Recently, an analysis of the correlation has been reported between SNSB subtests and the degree of amyloid burden measured by standardized uptake value ratio on C11

Pittsburgh compound B-PET in AD and MCI patients.[23] In the MCI group, the frontal cortex was significantly correlated with the RCFT:copy/DR. Meanwhile, in the AD group, all brain regions were associated with the copy time of the RCFT. The RCFT:recognition and the SVLT-E:recognition also showed a significant correlation with the frontal cortex of the AD group.

Regarding non-AD pathology, a large-sample study was reported, analyzing the relationship between SNSB performance and cortical thickness in amyloid-negative subcortical vascular cognitive impairment (svMCI: n=116 and SVaD: n=82) and amyloid-negative NC (n=198).[24] Looking at the main results, the areas related to the deterioration of working memory (the DST:B) were bilateral inferior frontal, right superior frontal, and middle frontal gyri. Decreased selective attention and cognitive flexibility (the K-CWST:CR) were associated with bilateral inferior frontal gyri. In particular, episodic memory (the SVLT-E:DR and the RCFT:DR) was shown to be associated with the frontal regions, not the medial temporal regions in this group.

Prediction of dementia conversion with the SNSB

Continuous efforts have been made to identify which neuropsychological factors play a decisive role in the morbidity of dementia in relation to dementia prevention. The CREDOS data showed that the annual conversion rates of early-onset MCI (EOMCI, onset <65 years) and late-onset MCI (LOMCI, onset ≥65 years of age) were significantly different (EOMCI 11.5% vs. LOMCI 23.3%).[25] In this study, the original SNSB subtests predicting the conversion to Alzheimer's disease differed in EOMCI and LOMCI were analyzed. In the case of LOMCI, verbal memory (the SVLT-E:DR) was the best predictor of conversion to AD, which was consistent with previous studies.[26,27] In contrast, visual memory (the RCFT:DR) and confrontation naming (the K-BNT) were identified as major predictors in the EOMCI group. These findings allow us to more actively manage specific cognitive factors that are important in the conversion to AD according to the onset age of MCI patients in the clinical setting. In addition, this suggests the possibility that the underlying pathology of EOMCI and LOMCI may be different.

Jang et al.[28] developed risk prediction models on the conversion of aMCI to dementia using a multivariate logistic regression model. They classified the aMCI according to 3 factors: MCI subtype, the severity of the RCFT:DR or the SVLT-E:DR, and memory dysfunction type. The dementia risk of multi-domain, late-stage severity and memory dysfunction in both verbal and visual was significantly higher than that of single-domain, early-stage, and verbal memory dysfunction alone, respectively. When the apolipoprotein E4 (APOE4) status was considered along with the neuropsychological tests, the severity factor of memory impairment was replaced by the factor APOE4. The developed models assigned different risk scores to each factor (age, modality, multiplicity, and severity (or APOE4)), and the dementia risk score (total score: 180 points or 220 points) is achieved by summing them up, and the predicted probability for dementia conversion according to the score is determined. Therefore, the developed risk prediction models provide specific information about the conversion of each individual to dementia by quantifying various related factors in an integrated way.

Using machine learning (ML) methods, Chun et al.[29] predicted conversion to dementia in patients with aMCI. In this study, the RCFT:DR was found to be a more important factor than the SVLT-E:DR. The interpretable ML developed in the study provides interpretable detailed information about dementia conversion of each patient by showing the contribution of each factor using various statistical values and graphs.

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Role of the SNSB as a golden standard

The SNSB has been serving as a gold standard in research to develop new cognitive tests. In particular, in the process of developing a new neuropsychological battery, The SNSB is often used for performance comparison to test the construct validity of new tests. The LICA, one of the 3 representative batteries for a comprehensive assessment of dementia in Korea, confirmed the correlation with the SNSB subtests to verify validity of its development.[4] In the subsequent paper, the inter-method reliability between the LICA and the SNSB was confirmed for MCI subtype classification.[30] Another tablet-based neuropsychological test battery, Inbrain Cognitive Screening Test, was analyzed for reliability and validity compared to the SNSB.[31] Additionally, the SNSB domain scores serve a standard role for validating scores provided by other tests, such as the MoCA Index score.[32]

SUMMARY AND CONCLUSIONS

The SNSB is a widely used tool for comprehensive neuropsychological assessment in Korea. The SNSB-II has updated the normative data of the original SNSB and has increased the reliability of cognitive function evaluation through model-based norms. The reliability and validity of the battery have been proven to be acceptable, making it a reliable tool that can be used where detailed cognitive function evaluation is required in clinical settings. The SNSB-II provides domain scores for domain follow-up and comparison between cognitive domains, thereby further expanding the range of its use. The SNSB-C, which consists of core tests for each cognitive domain, derives a composite score to directly compare changes in GCF according to follow-up. In addition, it can be used in various situations depending on the need as the required time is shortened. The full version of the SNSB includes various tests that can screen for Gerstrmann's syndrome, hemispatial neglect, aphasia, and apraxia, so it is an evaluation tool that can faithfully serve as a screening battery. The SNSB has been also serving as the gold standard for neuropsychological evaluation in Korea for a long time. In addition, the role of the SNSB can be easily confirmed in various studies showing clinical usefulness, such as analyzing different characteristics of various types of dementia, exploring test-specific neural correlates, and identifying cognitive factors predicting conversion to dementia.

However, despite such high SNSB status in Korea, there has been no validation paper for the original SNSB and the SNSB-II, so it is not easy to check the contents of SNSB abroad. If checking references cited in papers using SNSB, most of them refer to the SNSB publisher. However, this does not provide any practical information about the SNSB for overseas readers. Papers on subtests included in the SNSB are also used as reference materials for the SNSB. Therefore, this review describes the history, test composition, standardization, and related research of the SNSB as a whole, focusing on the SNSB-II. Furthermore, we hope this paper provides specific information about the SNSB, a neuropsychological test battery developed in Korea, to overseas readers and reviewers.

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