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Review Article

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

Hui Jin Ryu [1] **Dong Won Yang** [2]

[1]Department of Neurology, Konkuk University Medical Center, Seoul, Korea
[2]Department of Neurology, Seoul St. Mary's Hospital, The Catholic University of Korea, Seoul, Korea

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Correspondence to
Dong Won Yang
Department of Neurology, Seoul St. Mary's Hospital, The Catholic University of Korea, 222 Banpo-daero, Seocho-gu, Seoul 06591, Korea.
Email: neuroman@catholic.ac.kr

ORCID iDs
Hui Jin Ryu
https://orcid.org/0000-0002-0045-5799
Dong Won Yang
https://orcid.org/0000-0002-4733-7298

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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.

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)

Table 1. (Continued) Composition of the SNSB-I

Domain/Subtest (score)	Description
Frontal/executive functions	
[19] Motor impersistence (N, B, Ab)	The examiner asks the subject to keep their eyes closed for 15 sec.
[20] Contrasting program (0–20)	When the examiner raises one finger, the subject must raise 2 fingers, and when the examiner raises 2 fingers, the subject must raise one finger. A total of 20 trials are performed.
[21] Go-no go (0–20)	The test is done right after the contrasting program. When the examiner raises one finger, the subject must raise 2 fingers, but when the examiner raises 2 fingers, the subject must not raise their fingers. A total of 20 trials are performed.
[22] Fist-edge-palm (N, B, Ab)	A set of movements consists of 3 consecutive movements: making a vertical fist, making a vertical palm edge, and tapping the desk with the palm. If 10 sets are performed correctly, it is scored as normal.
[23] Alternating hand movement (N, B, Ab)	With one hand clenched into a fist and the other hand open, perform a motion of changing the shape of both hands at the same time. If 10 alternating movements are performed correctly, it is scored as normal.
[24] Alternating square & triangle (N, D, P)	The patient is asked to copy a line drawing in which squares and triangles with no base are continuously drawn without regularity.
[25] Luria loop (N, D, P)	The subject is asked to copy a line drawing in the shape of a spring that rotates 3 times.
[26-1] COWAT:semantic (animal, supermarket) (0–Infinity)	The subject is asked to voluntarily report words belonging to each category (animal and supermarket) for 1 min each.
[26-2] COWAT:phonemic (/g/, /o/, /s/; 0–Infinity)	The subject is asked to voluntarily report words starting with each phonemic (3 Korean consonant letters: /g/, /o/, and /s/) for 1 min each.
[27-1] K-CWST:WR (120 sec/60 sec; 0–112)	The test consists of 112 words printed in a different color from its meaning. The list contains 4 colors (blue, yellow, red, and black) and each appears 28 times in random order. The subject is asked to read out the words as fast as possible. The time limit is 2 min, in the case of the SNSB-C it is 1 min.
[27-2] K-CWST:CR (120 sec/60 sec; 0–112)	This section is done right after the K-CWST:WR. The subject is asked to say the color of the words, not the word itself, as fast as possible. Everything else is the same as the K-CWST:WR.
[28] DSC (0–133)	At the top of the test paper is a reference table with the numbers 1 to 9 and the symbol corresponding to each number. 133 vertically paired rows are given below the reference table. The upper column of the paired row is randomly numbered, but the lower column is blank. The subject is asked to write down the symbols corresponding to the numbers in the lower column for 2 min in the order presented as quickly as possible.
[29-1] K-TMT-E:part-A (0–300 sec; 0–15 errors)	The numbers 1 through 15 are written in a scrambled way on paper. The subject is asked to connect the numbers 1 to 15 in sequence using a pencil as quickly as possible. The time limit is 300 sec. The score measures the time it took to complete the task and the number of errors.
[29-2] K-TMT-E:part-B (0–300 sec; 0–16 errors)	The numbers (1 through 15) and the days of the week (Monday through Sunday) are written in a scrambled way on paper. The subject is asked to connect the numbers and days of the week, alternately and in sequence, starting with number 1. Everything else is the same as the K-TMT-E:part-A.

N: normal, B: borderline, Ab: abnormal, D: deformed, P: perseveration, SNSB-II: Seoul Neuropsychological Screening Battery, 2nd Edition, SNSB-C, Seoul Neuropsychological Screening Battery-Core, DST:F: Digit Span Test:forward, DST:B: Digit Span Test:backward, K-BNT: Korean-Boston Naming Test, S-K-BNT: Short Form of the Korean-Boston Naming Test, RCFT: Rey Complex Figure Test, CDT: Clock Drawing Test, SVLT-E: Seoul Verbal Learning Test-Elderly's version, IR: immediate recall, DR: delayed recall, K-TMT-E: Korean-Trail Making Test-Elderly's version, WR: word reading, COWAT: Controlled Oral Word Association Test, K-CWST: Korean-Color Word Stroop Test, CR: color reading, DSC: Digit Symbol Coding.

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.

$$\text{Recognition Discriminability Index} = 1 - \left(\frac{False\ Positive + 12 - True\ Positive}{24}\right)$$

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The frontal/executive functions domain consists of the Controlled Oral Word Association Test (COWAT), Korean-Color Word Stroop Test (K-CWST), Digit Symbol Coding (DSC), Korean-Trail Making Test-Elderly's version (K-TMT-E), and several motor and copy tasks that measure motor regulation and perseveration. The COWAT includes 2 fluency tests (category fluency and phonemic fluency). Through motor and copy tasks such as Luria loop, alternating square & triangle, and alternating hand movement, it is possible to judge perseveration problems and motor execution or control dysfunction.

NORMALIZATION, RELIABILITY, AND VALIDITY

Normalization

The SNSB updated the normative data in 2012. The updated version includes additional new cognitive tests, such as the vigilance test, CDT, DSC, and K-TMT-E. The standardization of the SNSB-II was done with 1,067 subjects (600 males, 467 females) recruited from 6 regions across the country. Compared with the original SNSB, the age range was expanded to 45–90 years old and divided into 9 groups at 5-year intervals, which made it possible to reliably evaluate early onset dementia in young adults and to detect cognitive decline in older adults. The level of education was divided into 7 groups, including the illiterate group and 17 years of education or more. For normative data, the mean and standard deviation (or the percentile) are provided for each group according to age and education level. For data with sex differences, statistics according to sex were additionally provided for reference in evaluation. For the original SNSB, measured raw scores were used for the normative data without adjustment. In this case, according to changes in age and educational level, the statistics may be reversed, contrary to the theoretical expectation. In contrast, the SNSB-II provides psychometrically improved norms and indicators using a model-based standardization procedure based on the theoretical probability distribution. Specifically, the mean and standard deviation were adjusted for subgroups based on the theory that the subgroup's performance is systematically affected by age and education level. This kind of standardization procedure ensures a stable trend of the normative data according to age and education level, without the reversal shown occasionally in the original SNSB.

Reliability

The reliability of the SNSB-II was reported as the test-retest method (n=41; mean age 59.86±10.55 years; mean education 10.22±4.94 years; test-retest interval 37.76±10.44 days). According to the intraclass correlation coefficient (ICC) analysis, the value for the RCFT:recognition was significant but low (0.48; $p<0.01$). However, all the other subtests showed high significant values (0.60–0.97; $p<0.001$) (**Table 2**). Among them, the calculation test showed the highest ICC value (0.97; $p<0.001$).

Table 2. Test-retest reliability of the SNSB-II

Range of ICC	No. of subtest	Subtest (ICC)
0.48	1	RCFT:recognition (0.48)
0.60≤ ICC <0.70	5	SVLT-E:recognition (0.60), RCFT:copy (0.62), SVLT-E:IR (0.66), RCFT:IR (0.66), SVLT-E:DR (0.69)
0.70≤ ICC <0.80	9	RCFT:DR (0.70), DST:B (0.71), Praxis:ideomotor (0.71), K-TMT-E:part-A (0.73), DST:F (0.74), COWAT:semantic (animal) (0.74), COWAT:semantic (supermarket) (0.74), COWAT:phonemic (0.78), CDT (0.78)
0.80≤ ICC <0.90	4	K-CWST:CR (0.88), K-TMT-E:part-B (0.88), K-BNT (0.89), DSC (0.89)
0.90≤ ICC <1.00	2	K-CWST:WR (0.90), Calculation (0.97)

SNSB-II: Seoul Neuropsychological Screening Battery, 2nd Edition, ICC: intraclass correlation coefficient, RCFT: Rey Complex Figure Test, SVLT-E: Seoul Verbal Learning Test-Elderly's version, IR: immediate recall, DR: delayed recall, DST:F: Digit Span Test:forward, K-TMT-E: Korean-Trail Making Test-Elderly's version, COWAT: Controlled Oral Word Association Test, CDT: Clock Drawing Test, K-CWST: Korean-Color Word Stroop Test, CR: color reading, K-TMT-E: Korean-Trail Making Test-Elderly's version, K-BNT: Korean-Boston Naming Test, DSC: Digit Symbol Coding, WR: word reading.

Validity

The SNSB-II reported a confirmatory factor analysis to verify the domain structure while making a 2-tier hierarchical structure by classifying each subtest into one of the 5 cognitive domains and additionally ramifying the memory subtests into the verbal or visual subdomains. The 2-tier domain model showed an adequate fit with the sample data (χ^2=471.82; df=123, p<0.001; CFI=0.96; TLI=0.95; RMSEA=0.056 [0.050, 0.061]; SMRM=0.042).

The results of verifying whether the quantitative subtests and domain scores of the SNSB-II discriminate between different cognitive groups were reported on the following subjects: normal control (NC; n=35; mean age 70.23±5.06 years), amnestic mild cognitive impairment (aMCI; n=30, mean age 72.07±6.65 years), vascular cognitive impairment no dementia (VCIND; n=31, mean age 69.35±8.43 years), AD dementia (n=30, mean age 70.80±9.27 years), and vascular dementia (VD; n=32, mean age 73.72±6.74 years). The results of the multivariate analysis of covariance (MANCOVA) for all the subtests with the SGDS, sex, and education level as the covariates showed a significant difference among groups (Wilks' Lamda=0.118; F=3.47; p<0.001). In the univariate tests for each subtest, group differences were significant in all the subtests. The post-hoc analysis with Bonferroni correction showed significant differences between NC and AD in all the subtests except for the DST:F. The MANCOVA results of domain scores with the SGDS as a covariate were also significant (Wilks' Lamda=0.325; F=9.77; p<0.001). The univariate test for each domain score showed significant group differences in all the domain scores. In the Bonferroni *post hoc* analysis, the NC group showed a significant difference from the AD and VD groups in all the domain scores.

DOMAIN SCORE, BRIEF VERSION, AND COMPOSITE SCORE

Domain score

The SNSB-II provides cognitive domain scores for the 5 cognitive domains. The cognitive domain scores provide a unified picture of each cognitive domain and allow us to keep track of the changes. **Table 3** shows the subtests selected for calculating each domain score. Most of the quantifiable tests in the SNSB-II are included to ensure the representativeness of each cognitive domain. Domain scores are generated through almost the same process as the standardization method of the SNSB-II. Therefore, the domain scores by themselves can be used for evaluation even without any follow-up. The first step in calculating the final domain scores is to define domain raw scores. Unlike other cognitive domain scores, the raw score for the attention domain is calculated as the sum of the raw scores from the DST:forward (DST:F) and the DST:backward (DST:B). For the other domains, each raw score is the average of the subtests' z-scores belonging to each domain. In this case, the z-score of each subtest is the standardized value as measured from the entire sample rather than the age-education subgroup. The following steps apply equally to all the domains. The mean and standard deviation for each subgroup according to the age-education group are calculated in the same way as in the normalization of individual SNSB-II tests. Finally, using this, standard scores such as percentile, z-score, and T-score are provided for each cognitive domain.

The brief version of the SNSB-II

The SNSB-C consists of 14 subtests that are essential to each cognitive domain (**Table 3**). It has a short test time (about 40 minutes), so it is easy to quickly evaluate a subject's cognitive function in a setting where it is difficult to perform tests with long test times such as a primary medical institution. The SNSB-C replaces some subtests in the SNSB-II with short

Table 3. Composition of SNSB-II, SNSB-C, and SNSB-D

Domain/Subtest	SNSB-II		SNSB-C		SNSB-D GCF
	Maximum score	Domain subtest	Subtest	Subtest for composite score	Maximum score
Attention					
[1] Vigilance test			●		
[2-1] DST:F	9	●	●	●	9
[2-2] DST:B	8	●	●	●	8
[3] Letter cancellation					
Language & related functions					
[4] Spontaneous speech					
[5] Comprehension	5	●	●		
[6] Repetition	15	●	●		
[7-1] K-BNT	60	●			
[7-2] S-K-BNT	15		●	●	15
[8] Reading					
[9] Writing					
[10] Finger naming					
[11] Right-left orientation					
[12] Body-part identification					
[13] Calculation	12				12
[14] Praxis:buccofacial					
[15] Praxis:ideomotor	5		●		
Visuospatial functions					
[16-1] RCFT:copy	36	●	●	●	36
[17] CDT	3	●			
Memory					
-					6 (orientation)
[18-1] SVLT-E:IR	36	●	●	●	
[18-2] SVLT-E:DR	12	●	●	●	48
[18-3] SVLT-E:recognition	24	●	●	●	12
[16-2] RCFT:IR	36	●			36
[16-3] RCFT:DR	36	●			36
[16-4] RCFT:recognition	24	●			12
Frontal/executive functions					
[19] Motor impersistence					3
[20] Contrasting program	20		●		3
[21] Go-no go	20	●	●		3
[22] Fist-edge-palm					3
[23] Alternating hand movement					
[24] Alternating square & triangle					
[25] Luria loop					3
[26-1] COWAT:semantic (animal, supermarket)	Infinity		● (animal)	● (animal)	20 (animal)
[26-2] COWAT:phonemic (/g/, /o/, /s/)	Infinity	●	● (/g/)	● (/g/)	15 (/g/)
[27-1] K-CWST:WR (120 sec/60 sec)	112		● (60 sec)		
[27-2] K-CWST:CR (120 sec/60 sec)	112	●	● (60 sec)	● (60 sec)	
[28] DSC	133	●	●	●	
[29-1] K-TMT-E:part-A	300		●		
[29-2] K-TMT-E:part-B	300	●	●	●	20

SNSB-II: Seoul Neuropsychological Screening Battery, 2nd Edition, SNSB-C, Seoul Neuropsychological Screening Battery-Core, SNSB-D: Seoul Neuropsychological Screening Battery-Dementia, GCF: global cognitive function, DST: Digit Span Test, F: forward, B: backward, K-BNT: Korean-Boston Naming Test, S-K-BNT: Short Form of the K-BNT, CDT: Clock Drawing Test, RCFT: Rey Complex Figure Test, SVLT-E: Seoul Verbal Learning Test-Elderly's version, IR: immediate recall, DR: delayed recall, COWAT: Controlled Oral Word Association Test, K-CWST: Korean-Color Word Stroop Test, WR: word reading, CR: color reading, DSC: Digit Symbol Coding, K-TMT-E: Korean-Trail Making Test-Elderly's version.

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forms. First, in the language domain, 15 items of the S-K-BNT are used instead of the 60 items of the K-BNT. Next, the score in the K-CWST is evaluated for performance over 60 seconds, not 120 seconds. Finally, in the case of the COWAT, only one semantic (animal) and one phonemic (/g/) are evaluated for each category.

Composite score

The SNSB-C provides a composite score indicating the overall level of cognitive ability.[12] The composite score, calculated with 10 out of 14 subtests of the SNSB-C, can be useful for tracking changes in overall cognitive function (**Table 3**). Like the SNSB-II domain score, the composite score is provided as a standard score (T-score) according to the age-education group. Therefore, it can be useful for evaluation even in situations where follow-up testing is not performed. The composite score-deriving process has 2 steps: calculating the representative score for each cognitive domain and giving the same weight. The SNSB-C composite score differs from the SNSB-II domain score in 2 major ways, in terms of its derivation method. One is that since the K-TMT-E scores have high negative skewness, log transformation (natural log of [300/K-TMT-E]) was performed. Second, when deriving the representative score for the memory domain, a double weight was assigned to the SVLT-E:DR. There are several differences between the subtests that derive the SNSB-C composite score and those deriving the SNSB-II domain scores. The main difference is that with respect to the SNSB-C composite score, the memory domain does not contain the visual part of the memory, only the S-K-BNT is used for the language domain, and the 60-second time limit is used for the K-CWST:color reading (CR).

On the other hand, there is another type of composite score called the Global Cognitive Function (GCF) score, which was developed and validated in the SNSB-Dementia version (SNSB-D)[13] based on the original SNSB. Since the tests included in the GCF score are all included in the SNSB-II except for a simple orientation test (questions about time and place), the GCF score of the SNSB-D can also be calculated if the SNSB-II is performed. The tests and scores included in the GCF score are presented in **Table 3**. The total score of the GCF score is 300, and different weights are given to each cognitive domain: attention (6%), language & related function (9%), visuospatial function (12%), memory (50%), and frontal/executive function (23%).

NORM COMPARISON BETWEEN THE ORIGINAL SNSB AND THE SNSB-II

The SNSB-II made extension of the quantitative data, such as the number of subjects, recruited age, and educational level classification, compared to the original SNSB. Also, unlike the original SNSB, the SNSB-II uses adjusted normative data instead of the collected raw data. Such a restandardization is expected to bring about a large difference in the normative data between the SNSB-II and the original SNSB even in the same age and education level groups of the same tests. Changes in the normative data that occur upon renormalization may reflect changes in cognitive function over time. It is also necessary to look into the impact of changes in the standardization method applied to the SNSB-II. In this section, the degree of change in normative data will be analyzed in the comparable common age-education subgroups of the original SNSB and the SNSB-II. In comparing norms, the following tests were excluded: (1) Tests added to the SNSB-II (the CDT, DSC, K-TMT-E, and K-CWST:60 sec), (2) A test that is also scored quantitatively in the SNSB-II, but not quantitatively in the original SNSB (the comprehension), (3) Tests with modified items or using other versions in the SNSB-II (the repetition and the S-K-BNT), (4) Tests in which the representative statistics were changed to percentile values in the SNSB-II (the calculation, praxis:ideomotor, contrasting program, and go-no go). In addition, only groups of the same age and education range were analyzed: (age: 4 divisions from 55 to 74 years old, education level: 5 divisions from illiterate to 12 years of education). The illiterate group aged 55 to 59 years was excluded from the analysis because it was not provided by the original SNSB. Finally, since the COWAT:phonemic and the K-CWST cannot be performed for illiterate people, normative data are not provided and thus not analyzed. It should be noted that the mean and standard deviation suggested by the norm in the SNSB-II are estimated values and not raw scores, so it violates the statistical assumption of the *t*-test. Despite such a limitation, *t*-tests were intentionally performed to give a rough impression of the extent to which the norm has changed.

Table 4 shows the statistical results for the comparable 28 normative data tables. Among the 20 primary data tables excluding 8 secondary ones (the DST:F-B, true positive, false positive, discriminability index, and inference), the average rates of change in the RCFT:copy (time), RCFT:IR, and RCFT:DR were greater than 25%. In most of the primary test scores (the K-BNT, SVLT, RCFT, COWAT:phonemic, COWAT:semantic [supermarket], DST, and K-CWST:word reading [WR] [Time]), there are more table cells where cognitive levels have increased by more than 10% than those that decreased by more than 10%. For the scores reflecting reaction time, an increase in the value corresponds to a decrease in cognitive function. Conversely, the data tables in the COWAT:semantic (animal), K-CWST:CR (correct), and K-CWST:CR (time) had a slightly more number of cells in which cognitive function decreased by more than 10%. In the tests of the K-BNT and the RCFT:copy (time), all age-education subgroups showed an increase in the cognitive function level. In the case of the RCFT:copy/IR/DR, there was an age-education subgroup in which the value in the SNSB-II was more than doubled compared to that of the corresponding original SNSB. It seems difficult to explain such a large change in normative data only with a change in generation characteristics. The norm update can be interpreted as bringing about a significant change due to the qualitative change in the normalization method.

STUDIES USING THE SNSB

Many studies using the SNSB have been actively conducted in various fields related to dementia. This section briefly introduces the main studies written in English demonstrating the clinical usefulness of the SNSB.

Cognitive characteristics from SNSB findings

By looking at how cognitive profiles differ according to various types of dementia, we can better understand the characteristics and underlying mechanisms of the diseases. It is known that cognitive decline in subjects with vascular cognitive impairment can be sensitively detected by executive function tests, particularly speed tests of executive function.[14] Kim et al.[15] analyzed the SNSB outcomes focusing on patients with pure subcortical vascular MCI (svMCI) and pure subcortical vascular dementia (SVaD), who are amyloid positron emission tomography (PET) negatives. The patients with svMCI showed significantly poorer performance than NCs in frontal functions (the COWAT and the K-CWST:CR), memory retrieval (the SVLT-E:IR/DR and the RCFT:IR/DR), and confrontational naming (the K-BNT).

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Table 4. Change of norm from the original SNSB to the SNSB-II

Domain/Subtest	Compared group	Change of norm mean			Rate of change					Sig. group*
		Lowest	Greatest	Average of absolute change	Lowest (%)	Greatest (%)	Average of absolute rate (%)	Group of less than 10%	Group of greater than 10%	
Attention										
DST:F	19	−0.12	0.92	0.29	−2.19	21.65	5.88	0	2	0
DST:B	19	−0.28	0.73	0.30	−6.65	30.86	10.13	0	6	1
DST:F-B†	19	−0.47	0.73	0.24	−21.66	64.60	14.16	5	5	0
Language & related functions										
K-BNT	19	2.52	10.48	5.06	5.92	39.92	14.08	0	12	8
Visuospatial functions										
RCFT:copy (score)	19	−1.19	17.93	2.99	−3.72	124.34	16.92	0	7	4
RCFT:copy (time)	19	−314.85	−37.03	137.08	−59.31	−16.14	36.33	19	0	15
Memory										
SVLT-E:IR	19	−0.35	5.31	2.02	−1.85	44.25	12.77	0	11	0
SVLT-E:DR	19	−0.78	2.29	0.67	−11.93	76.33	14.48	1	9	0
SVLT-E:recognition (score)	19	−0.60	1.97	0.65	−2.82	10.59	3.32	0	1	2
SVLT-E:recognition (TP)	19	−0.72	1.59	0.47	−6.55	18.71	4.98	0	2	1
SVLT-E:recognition (FP)	19	−1.16	0.61	0.36	−39.29	52.14	19.76	6	5	1
SVLT:E:recognition (discriminability index)	19	−2.70	8.14	2.69	−3.05	10.50	3.28	0	1	2
RCFT:IR	19	−2.71	5.23	2.10	−16.23	107.17	25.57	3	10	1
RCFT:DR	19	−2.95	6.35	1.83	−19.33	163.66	26.38	2	8	2
RCFT:recognition	19	−0.98	2.73	1.00	−4.62	18.10	5.63	0	3	3
RCFT:recognition (TP)	19	−0.29	2.76	1.30	−2.81	48.00	16.46	0	15	10
RCFT:recognition (FP)	19	−1.03	1.19	0.61	−30.12	148.75	43.11	4	13	3
RCFT:recognition (discriminability index)	19	−4.04	11.40	4.22	−4.57	18.14	5.70	0	3	3
Frontal/executive functions										
COWAT:animal	19	−2.28	2.29	1.21	−15.91	15.27	8.10	4	1	0
COWAT:supermarket	19	−2.03	5.78	1.37	−12.65	74.58	10.89	2	3	0
COWAT:phonemic (/g/)	16	−0.67	3.40	1.05	−11.90	50.97	16.08	1	9	2
COWAT:phonemic (/o/)	16	−0.22	2.60	0.99	−3.41	48.05	17.56	0	8	0
COWAT:phonemic (/s/)	16	−1.67	3.09	1.06	−23.03	44.14	15.25	3	7	1
COWAT:phonemic (total)‡	16	−1.81	9.10	2.74	−9.81	44.03	13.71	0	8	2
K-CWST:WR (time per item)	16	−0.21	0.01	0.11	−23.33	1.14	12.35	9	0	4
K-CWST:CR (time per item)	16	−0.23	0.25	0.13	−15.44	17.78	8.82	3	5	1
K-CWST:CR (correct)	16	−13.08	12.25	7.25	−14.72	17.10	8.69	3	2	1
K-CWST:CR (inference)§	16	−0.20	0.39	0.17	−24.10	84.78	32.07	1	12	5

SNSB: Seoul Neuropsychological Screening Battery, SNSB-II: Seoul Neuropsychological Screening Battery, 2nd Edition, DST: Digit Span Test, F: forward, B: backward, K-BNT: Korean-Boston Naming Test, RCFT: Rey Complex Figure Test, SVLT-E: Seoul Verbal Learning Test-Elderly's version, IR: immediate recall, DR: delayed recall, TP: true positive, FP: false positive, COWAT: Controlled Oral Word Association Test, K-CWST: Korean-Color Word Stroop Test, WR: word reading, CR: color reading.
*Number of age-education subgroups significant at $p<0.05$ of t-test. It should be noted that the statistical assumptions for t-test does not hold in this analysis.
†Forward score minus backward score in the Digit Span Test.
‡The sum of the 3 COWAT:phonemic (/g/, /o/, and /s/) scores.
§The K-CWST:CR (time per item) score minus the K-CWST:WR (time per item) score.

In the comparison of SVaD and svMCI, the patients with SVaD performed significantly lower than patients with svMCI in all subtests except the DST. Regarding verbal and visual recognition memory and visuoconstruction (the RCFT:copy), statistically significant differences were shown between svMCI and SVaD, but there was no significant difference between svMCI and NC.

According to main studies comparing VCIND and non-vascular mild cognitive impairment (nv-MCI), VCIND has the most obvious difficulties in processing speed and executive function; whereas nv-MCI suffers the most from delayed memory.[16] Hong et al.[17] compared the neuropsychological results of AD and subcortical ischemic vascular dementia (SIVD) in the CREDOS study using the original SNSB data. Compared to the AD group, the

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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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