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REPLICATION AND CONSTRUCT VALIDATION OF THE BARROW NEUROLOGICAL INSTITUTE SCREEN FOR HIGHER CEREBRAL FUNCTION WITH A SWEDISH POPULATION

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A Swedish translation of the Barrow Neurological Institute Screen for Higher Cerebral Functions was administered to 52 normal control subjects and 36 patients with well-documented brain dysfunction. Findings replicated those reported in American samples. Level of performance was strikingly similar between Swedish controls and American controls, especially in individuals between 15 and 39 years. Swedish patients with brain dysfunction performed at levels significantly below the Swedish control subjects. The sensitivity of the test was 83% (correctly classifying 30 of 36 patients); patients with a higher level of education were misclassified. The present study replicates earlier findings and adds to the construct validity of the Barrow Neurological Institute Screen. This test may also prove useful for studying rehabilitation outcomes in Swedish patients.

Key words: neuropsychological screening, BNI screen, neurorehabilitation, neuropsychology.

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INTRODUCTION

During past decades neuropsychological knowledge has increased dramatically, and neuropsychological assessment now plays an important role in the evaluation of brain dysfunctional patients (1, 2). Neuropsychological assessment may be conducted for many reasons: to aid in diagnosis, to provide potentially valuable information for rehabilitation management and care, to evaluate the efficacy of different rehabilitation methods, and to conduct research (3). A comprehensive neuropsychological investigation often requires several hours of testing (3, 4). Clinically, however, the time available to examine patients and the patients' condition limit the length of neuropsychological investigations. Therefore, a short, standardized neuropsychological screening test with wide applicability could be quite useful clinically (5).

During the past 20 to 30 years, a number of screening tests have been developed, many to screen patients with possible dementia (6–11). Typically, these screening tests do not provide clinicians with adequate information to establish a preliminary neurological diagnosis of focal, bilateral, diffuse, or lateralizing brain injury (12). Other screening tests have been developed to assess patients with traumatic brain injury, stroke, and various neurological conditions (7, 10, 13). Many of these instruments, however, do not systematically assess patients' emotional characteristics, which can be a valuable source of information for both the assessment process per se and the efficacy of rehabilitation. For example, the capacities to control impulses and to perceive and express affect are important for social interaction and whether these abilities are intact can influence the rehabilitation process (14).

The Barrow Neurological Institute (BNI) Screen for Higher Cerebral Functions (BNIS) is a short screening test developed to systematically assess a variety of higher cerebral functions that would aid in differential diagnosis and treatment planning (15). The initial rationale for developing the BNIS was to provide examiners with both qualitative and quantitative information about cerebral dysfunction. An important component of this test is a prescreening measure that systematically helps an examiner to determine whether an individual has adequate cooperation, arousal, and language skills to be examined. Assuming that these basic functions are intact, the screen then permits the systematic assessment of speech and language functions, orientation, attention/concentration, visuospatial and visual problem solving skills, memory, affect, expression, perception, and awareness (16). Sampling a wide range of behaviors, the BNIS has proven to be a rapid, reliable, and valid assessment of higher cerebral functions (2, 17).

The purpose of this study was to assess the construct validity of the BNIS in a Swedish population. If a Swedish translation of this test replicated the findings in American populations, it would establish the BNIS as a potentially helpful tool for assessing Swedish brain dysfunctional patients and for predicting rehabilitation outcomes as has been done with an American sample (14, 18). The present study compared the performance of healthy Swedish people with Swedish patients with brain injury and with data from American control subjects (19).

MATERIALS AND METHODS

Subjects

An invitation letter was sent to 519 citizens of Malmö between 30 and 90 years who were randomly recruited from the municipality registry. The

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Table I. *Demographic characteristics and test performance of 36 Swedish patients and 52 controls and 200 American controls. Mean values (standard deviation in parentheses)*

Variable	Swedish patients	Swedish controls	American controls
Age (years)	52.0 (16.6)	56.5 (15.6)	46.7 (20.4)
Education (years)	10.3 (3.0)	10.4 (3.3)	13.8 (2.4)*
Lesion Chron. (mo)	28.5 (51)	NA	NA
BNI total score	40.2 (6.5)	45.6 (3.1)**	45.5 (3.6)
Sex			
Females	11	25	144***
Males	25	27	56

* $p < 0.001$ for Swedish vs American controls; ** $p < 0.001$ for Swedish patients vs controls; *** $p = 0.002$ for Swedish vs American controls.

response rate was 45%. Sixty-four subjects were then invited to a medical and neuropsychological examination after undergoing a preliminary interview by telephone. The aim was to recruit 50 healthy subjects, proportionally distributed between the ages of 30 to 89 years (by decade). The inclusion criteria were no brain dysfunction according to medical history, examination, or computed tomography (CT) of the brain; no psychiatric illness; no dyslexia; Swedish as their primary language; no colour blindness; no serious vision or hearing problems; and no acute illness according to medical examination. All individuals older than 50 years were examined by CT of the brain to exclude subjects with pathological conditions. The subjects were recruited consecutively until the 10 age groups were filled. Of the 64 subjects examined, 12 were excluded: three each due to dyslexia, head trauma, and depression, two due to infarction revealed by the CT, and one due to migraine headaches. Ultimately, the control group was composed of 52 subjects (mean age 56.5 years, age range, 30–87 years). There were 25 women (mean age, 58.8 ± 15.7 years) and 27 men (mean age, 54.4 ± 15.3 years, Table I).

The patient group ($n = 36$: mean age, 52 years; age range, 22–76 years) was recruited consecutively among brain dysfunctional patients who had undergone a neuropsychological examination. The patient group consisted of inpatients and members of a day-care unit who had come to the Department of Geriatric Medicine of Malmö University Hospital for a neuropsychological evaluation. There were 25 men (mean age, 54.4 ± 15.6) and 11 women (mean age, 46.6 ± 15). In all cases, brain injury was confirmed by CT or cerebral xenon blood flow studies. The patients' diagnoses were classified according to the ICD-9 system (Table II) (20).

Chronicity (time since injury), level of education, and diagnoses were obtained from patients' medical records and interviews with patients. All subjects who had passed the Swedish "gymnasium" were considered to have a "high" level of education and those who had not reached this level were considered to have a "low" level of education.

There were 200 American controls (144 females, 56 males, Table I); their data are published elsewhere (19).

Table II. *Diagnostic categories of 36 Swedish patients with brain injury*

Diagnostic category	No. patients (%)
Hemorrhage	7 (19)
Infarction	10 (28)
Encephalitis/meningitis	1 (3)
Traumatic brain injury	14 (39)
Dementia	2 (5)
Anoxia	2 (5)

Table III. *Subscales and items of the BNI Screen for Higher Cerebral Function*

Subscale	Range of possible scores
Prescreening items (maximum score = 9)	
Level of consciousness	1–3
Basic language	1–3
Level of cooperation	1–3
Speech and language functions (maximum score = 15)	
Fluency of speech	0–1
Paraphasic errors	0–1
Dysarthric speech	0–1
Language comprehension	0–2
Naming	0–1
Sentence repetition	0–2
Reading	0–1
Writing (copying)	0–1
Writing (dictation)	0–1
Spelling (irregular)	0–1
Spelling (phonetic)	0–1
Arithmetic (alexia)	0–1
Arithmetic (dyscalculia)	0–1
Orientation (maximum score = 3)	
Right–left orientation	0–1
Orientation to place	0–1
Orientation to time (date)	0–1
Attention/concentration (maximum score = 3)	
Arithmetic (memory and concentration)	0–1
Digit repetition (forward)	0–1
Digit repetition (backward)	0–1
Visual spatial and visual problem solving (maximum score = 8)	
Visual object recognition	0–1
Constructional praxis (dominant hand)	0–1
Constructional praxis (nondominant hand)	0–1
Visual scanning	0–2
Visual sequencing	0–1
Pattern copying	0–1
Pattern recognition	0–1
Memory (maximum score = 7)	
Delayed recall for words	0–3
Number–symbol associations	0–4
Affect (maximum score = 4)	
Generating happy vs angry affect	0–1
Perception of facial affect	0–1
Affect control/appropriateness	0–1
Generation of spontaneous affect	0–1
Awareness (maximum score = 1)	
Awareness vs performance	0–1

From Prigatano GP, Wong JL. Cognitive and affective improvement in brain dysfunctional patients who achieve inpatient rehabilitation goals. Arch Phys Med Rehabil 1999; 80: 77–84. With permission from W. B. Saunders.

Procedure

All subjects underwent a physical examination by a physician (data not reported). The neuropsychological investigation included the BNIS and was conducted by two psychologists at the clinic who were experienced in neuropsychological testing.

The BNIS consists of 30 different items grouped together into seven clinically relevant factor scores with a maximum (total) score of 50 (Table III). The instrument takes 15–20 minutes to administer.

Statistics

Group means were compared with a Mann-Whitney U-test if not

Table IV. *Mean BNIS total score and standard deviation for three different age ranges of the Swedish and American control groups*

	Swedish controls		American controls		
Age range	No.	Mean (SD)	No.	Mean (SD)	*p*
15–39	10	47.6 (2.38)	93	47.5 (2.38)	NS
40–59	18	46.7 (2.47)	37	45.0 (3.50)	NS
60–84	24	43.9 (3.17)	70	43.1 (3.48)	NS

BNIS = Barrow Neurological Institute Screen for Higher Cerebral Functions.

otherwise stated. The Swedish and the American sample were compared by *t*-tests. Spearman's correlation coefficients were calculated to determine the relationship of age and education to BNIS scores. Proportional differences between groups were compared with a χ^2 test.

RESULTS

Swedish vs American controls

The mean BNIS total score for the Swedish controls was 45.6 ± 3.1, which is consistent with the mean for the American controls 45.5 ± 3.6 (Table I). BNIS total score did not differ between males and females in either the Swedish controls (males, mean 46.1 ± 3.1; females, mean 45.0 ± 3.0) or the American controls (males, mean 45.8 ± 3.8; females, mean 45.4 ± 3.5). The proportions males and females between the Swedish and the American controls differed significantly ($p = 0.002$; Table I). Education by years was not significantly correlated with test performance for the Swedish control group ($r = 0.2$, $p < 0.16$) but was for the American controls ($r = 0.31$, $p < 0.001$).

Age was a major influence on test performance for both the Swedish ($r = -0.59$; $p < 0.0001$) and American controls ($r = -0.55$, $p < 0.0001$). Performance tended to decline as age increased. There were no significant differences in mean BNIS total score between the Swedish and American control groups for three age ranges (15–39, 40–59, and 60–84 years, Table IV).

Table V. *Comparison of performance between Swedish brain-injured and controls on BNIS as a function of educational level*

Performance on BNIS	Brain-injured	Control	*p*
Low Education			
No. patients	18	30	
Mean (range)	38.1 (17.5–45)	44.9 (39–50)	<0.0001
SD	6.66	3.07	
High Education			
No. Patients	17	22	
Mean (range)	42.5 (28.5–48)	46.5 (39–50)	<0.05
SD	5.77	3.0	

BNIS = Barrow Neurological Institute Screen for Higher Cerebral Functions, SD = standard deviation, NS = not significant.

p value between low and high education within the brain-injured group: <0.05.

p value between low and high education within the control group: NS.

Table VI. *Comparison between mean individual factor scores for Swedish patients with brain injury and controls*

	Swedish controls mean (SD)	Swedish brain-injured mean (SD)	*p* value
Language	14.89 (0.38)	13.38 (2.92)	<0.001
Orientation	2.98 (0.14)	2.69 (0.62)	<0.01
Attention	2.52 (0.75)	2.06 (0.92)	<0.01
Visuospatial	6.63 (1.25)	5.36 (1.66)	<0.001
Memory	5.21 (1.79)	3.94 (1.97)	<0.01
Affect	3.71 (0.7)	3.19 (0.92)	<0.001
Awareness	0.62 (0.49)	0.58 (0.50)	NS

Swedish patients vs Swedish controls

There were no differences between the Swedish patient and control groups in terms of age, sex, or education (Table I).

The mean BNIS total score of the patients with brain injury was lower than that of the controls ($p < 0.001$). Chronicity ($r = -0.107$) and age ($r = 0.232$) were not significantly related to performance but education was ($r = 0.568$, $p < 0.001$). The mean BNIS total scores of patients with "high" ($n = 17$, mean BNIS score = 42.5, S.D. = 5.77, range = 28.5–48) and "low" ($n = 18$, mean BNIS score = 38.1, S.D. = 6.66, range = 17.5–45) levels of education were significantly different ($p < 0.05$; Table V).

In addition to the BNIS total score, the individual subscale scores were compared for patients and controls (Table VI). Performances on all subscales but awareness were significantly different between the two groups. On the awareness subscale, patients with brain injury were significantly more likely to overestimate (36%) their performance than controls who were more prone to predict correctly (63.5%) or to underestimate (19%) their test performance ($p < 0.05$). On the awareness subscale, 90.2% of the American controls correctly predicted their performance compared with 63.5% of the Swedish controls.

The ability to predict performance on the memory task was also related to overall performance on the BNIS. Among individuals in the brain-injured group who underestimated or correctly predicted their performance on this scale, their mean BNIS total score was 43.3 (S.D. = 3.66, $n = 23$) compared with 34.7 (S.D. = 6.73, $n = 13$, $p < 0.001$) for those who overestimated their mean score. In the control group, the mean BNIS total score for those who underestimated or correctly predicted their memory performance was 46.1 (S.D. = 3.02, $n = 43$) compared with 43 (S.D. = 2.18, $n = 9$; $p < 0.01$) for those who overestimated their performance.

Finally, the sensitivity, specificity, false-positive, and false-negative ratios were calculated at the recommended cut-off level on the BNIS total score for detecting brain impairment (see ref. 21 for details). The sensitivity was 83% and the specificity was

46%. The false-positive ratio was 48%, and the false negative ratio was 20% (i.e. 30 of the 36 patients were correctly classified as brain-injured). All those misclassified as not being brain-injured had a "high" level of education.

DISCUSSION

The present study demonstrates that a Swedish translation of the BNIS is potentially a sensitive measure for detecting and measuring cerebral dysfunction among the Swedish population. The Swedish control group also performed at a level comparable with their American counterparts. Age and performance were significantly correlated in both the American and Swedish control groups and at a comparable level ($r = -0.55$ and -0.59, respectively). The findings extend the construct validation of this instrument.

Educational levels significantly correlated with the performance of the American controls but did not reach statistical significance in the Swedish controls. However, education has been shown to influence performance on cognitive testing (22). With a larger sample size, educational level may have influenced performance in the Swedish controls.

The Swedish brain dysfunctional group clearly performed at a level lower than the Swedish controls on the BNIS. These data suggest that the BNIS discriminates Swedish brain dysfunctional patients from normal controls.

In both cultures, the role of education in influencing test performance was clearly seen in brain dysfunctional patients. This finding suggests that considering level of education when interpreting the BNIS total score may be useful. Such a trend has been seen in other aspects of neuropsychological test interpretation (23). Ultimately, different "cut-off" scores, depending on the educational level of the individual for which the test is being administered, may be needed. Presently, however, age-corrected *t*-scores are available, at least for the American population (19).

The individual subscale scores also separated patients and controls on all factors except awareness. Earlier studies by Prigatano et al. (21) and Rosenstein et al. (24) have shown significant differences between brain-injured and controls on the item awareness versus performance, but in the Swedish sample there was no difference on this factor. Brain-injured individuals tended to overestimate their performance, and the performance of the Swedish controls was consistent with earlier studies (16). The ability to estimate one's performance correctly on recalling three words with distraction was related to the level of performance on the BNIS as reflected by the total score in both patients with brain injury and controls. Thus, this variability may also need to be considered when interpreting findings. Unlike the American population, Swedish controls tended to underestimate their abilities, a finding that may reflect a cultural difference.

The difference between the brain-injured group and the controls on mean individual factor scores at the three subscales language, visuospatial and affect all reached the highest significance ($p < 0.001$) (Table VI). The importance of these three subscales in diagnosing right and left hemispheric lesions is stated by Prigatano et al. (21). Future studies will specifically cross validate this finding.

In addition to its use as a diagnostic instrument (24), the BNIS has been used to predict the outcome of neurorehabilitation (18, 14). In a study of 106 patients with acute brain lesions, age-corrected total scores on the BNIS at admission and discharge were higher for individuals who achieved their rehabilitation goals than for those who did not. Moreover, the amount of cognitive improvement, as measured by the BNIS, was related to more positive outcomes. Improvement in *both* cognitive and affective functioning as measured by the BNIS was related to rehabilitation outcome (14). Patients who ultimately achieved their rehabilitation goals more accurately predicted their memory performance (a possible measure of impaired awareness) and generally showed more spontaneous affect over the course of rehabilitation than those who did not.

Affective functions are often neglected by existing screening tests and more extensive neuropsychological test batteries. This may have resulted in neuropsychological tests being less useful in predicting rehabilitation outcome. Prigatano & Wong (14) have suggested that inpatient neurorehabilitation of brain dysfunctional patients should foster not only improvement in cognitive functioning but should also help patients improve their spontaneous demonstration of affect, their capacity to perceive facial affect, and their capacity to generate affect in tone of voice.

Whether the findings of Prigatano & Wong (14) can be replicated in the Swedish population awaits to be demonstrated. The present findings, however, are encouraging insofar as they suggest that previously observed relationships between BNIS test performance and brain dysfunction in American patients are similar to those in Swedish patients with brain injury. In particular, the performance of normal controls on the BNIS seems strikingly similar between Americans and Swedes.

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