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Concurrent Validity of CNS Vital Signs in Patients with Mild Traumatic Brain Injury

Shawnda C. Lanting, PhD
Copeman Healthcare Centre & University of British Columbia

Grant L. Iverson, PhD
University of British Columbia & Copeman Healthcare Centre

Rael T. Lange, PhD
Defense and Veterans Brain Injury Center, Walter Reed National Military Medical Center
& University of British Columbia

Abstract

Objective: This study examined the concurrent validity of computerized cognitive testing in a sample of patients with mild traumatic brain injuries (MTBIs).

Design: The relation between computerized and traditional neuropsychological testing was examined using Pearson correlation analyses.

Participants: Fifty patients who met the WHO Collaborating Center Task Force criteria for MTBI were included. A substantial minority (28%) had a trauma-related abnormality on day-of-injury CT (i.e., a "complicated MTBI").

Setting: Recruited from the Emergency Department of Vancouver General Hospital.

Main Outcome Measure: Neuropsychological testing (approximately 6-8 weeks post injury) included CNS Vital Signs (CNS-VS), which generates a Neurocognition Index (NCI) and five primary domain scores, and a battery of traditional tests selected from the Neuropsychological Assessment Battery (NAB), the Reynolds Intellectual Screening Test, and the Wechsler Test of Adult Reading.

Results: The NCI was significantly correlated with estimates of intellectual ability ($r=.33$, $r=-.41$), the NAB Attention ($r=.40$) and Memory ($r=.36$) Indexes, and several individual tests. CNS-VS Memory was significantly correlated with the NAB Memory Index ($r=.34$), but only correlated with one individual memory test. CNS-VS Complex Attention was correlated with only one attention test. CNS-VS Cognitive Flexibility and CNS-VS Reaction Time were correlated with the NAB Attention Index ($r=.39$, $r=.36$, respectively) and three attention tests. CNS-VS Psychomotor Speed was correlated with the NAB Attention Index ($r=.49$), five attention tests, the NAB Memory Index ($r=.58$), and four memory tests.

Conclusions: Overall, the CNS-VS domain scores were positively correlated with several traditional tests assumed to measure similar constructs. There were both expected and unexpected significant correlations between computerized and traditional testing.

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DVBIC
DEFENSE AND VETERANS BRAIN INJURY CENTER

Walter Reed National Military Medical Center

Background: Computerized testing is a time- and cost-efficient methodology for assessing cognitive functioning in clinical practice and research. The authors of a joint position paper of the American Academy of Clinical Neuropsychology and the National Academy of Neuropsychology have encouraged systematic and thorough research relating to the reliability and validity of computerized neuropsychological testing with healthy and clinical samples (Bauer et al., 2012). The purpose of this study is to examine the concurrent validity of computerized cognitive testing in a sample of patients following mild traumatic brain injury (MTBI).

Methods: Participants were recruited from the Emergency Department of Vancouver General Hospital. Fifty patients who met the WHO Collaborating Center Task Force criteria for MTBI were included in this study. A substantial minority (28%) had a trauma-related abnormality on day-of-injury CT (i.e., a "complicated MTBI"). The demographic information of the participants is presented in Table 1. The participants had a mean education of 14 years and were in the upper end of the average range in estimated intellectual ability.

Table 1. Demographics of the MTBI Sample

N	50
Age (years)	*M*= 30.1(*SD* = 9.1); Range = 19-55
Education (years)	*M* = 14.5 (*SD* = 2.3); Range = 11-22
Sex	Male = 37; Female = 11
MTBI Classifications	Uncomplicated = 35*; Complicated = 14

*One subject did not undergo a CT scan.

Neuropsychological testing was administered approximately 6-8 weeks post injury. The assessment battery included CNS Vital Signs (CNS-VS) and a battery of traditional tests selected from the Neuropsychological Assessment Battery (NAB), the Reynolds Intellectual Screening Test (RIST), and the Wechsler Test of Adult Reading (WTAR).

CNS-VS is comprised of seven common neuropsychological measures, including verbal and visual memory, finger tapping, symbol digit coding, a Stroop test, a shifting attention test, and a continuous performance test. In addition to providing an overall performance index score (Neurocognition Index), the original battery generates 15 primary scores, which are used to calculate five domain (index) scores: Memory, Psychomotor Speed, Reaction Time, Cognitive Flexibility, and Complex Attention.

Results: Descriptive statistics for WTAR, RIST, NAB (domain and subtests scores), and CNS-VS (domain scores) performance are presented in Table 2.

Table 2. Performance on the NAB Subtests and CNS-VS Domain Scores.

	M	***SD***
RIST Index	109.0	10.1
WTAR Standard Score	111.4	10.9
NAB Attention Index Standard Score	103.7	12.4
NAB Memory Index Standard Score	102.4	13.3
NAB Digits Forward T Score	51.1	8.3
NAB Digits Backward T Score	52.4	8.5
NAB Dots T Score	55.5	6.7
NAB N&L Part A Speed T Score	52.1	9.9
NAB N&L Part A Errors T Score	49.4	10.9
NAB N&L Part B Efficiency T score	52.4	8.2
NAB N&L Part C Efficiency T score	48.8	8.8
NAB N&L Part D Disruption T score	48.8	11.4

	M	*SD*
NAB Driving Scenes T Score	51.6	9.6
NAB List Learning List A Immediate Recall T score	50.4	8.9
NAB List Learning List A Short Delayed Recall T score	53.5	10.8
NAB List Learning List A Long Delayed Recall T score	52.3	11.3
NAB Shape Learning Immediate Recognition T score	54.3	7.6
NAB Shape Learning Delayed Recognition T score	52.5	8.1
NAB Story Learning Phrase Unit Immediate Recall T Score	50.6	9.6
NAB Story Learning Phrase Unit Delayed Recall T score	49.7	7.6
NAB Daily Living Memory Immediate Recall T score	50.9	10.4
NAB Daily Living Memory Delayed Recall T Score	48.6	12.1
NAB Visual Discrimination T Score	52.1	7.9
NAB Design Construction T Score	54.8	9.5
NAB Mazes T Score	53.3	6.6
NAB Categories T Score	52.0	10.2
NAB Word Generation T Score	51.3	11.1
CNS-VS Neurocognition Index Standard Score	98.3	14.7
CNS-VS Memory Standard Score	97.1	13.4
CNS-VS Psychomotor Speed Standard Score	103.1	15.5
CNS-VS Reaction Time Standard Score	99.5	13.6
CNS-VS Complex Attention Standard Score	94.9	21.3
CNS-VS Cognitive Flexibility Standard Score	101.9	22.1

Pearson correlation coefficients between the traditional neuropsychological measures and the CNS-VS domain scores are presented in Table 3. In addition, NAB and CNS-VS intercorrelation matrices are presented in Tables 4 and 5 respectively. The NCI was significantly correlated with estimates of intellectual ability (WTAR r=.33, RIST r=.41). CNS-VS Psychomotor Speed was also correlated with estimates of intellectual ability (RIST, r=.30, WTAR, r=.36). The NCI was significantly correlated with the NAB Attention (r=.40) and Memory (r=.36) Indexes, and several individual tests.

There are several tests of learning and memory on the NAB. These tests have mostly small to medium intercorrelations (Table 4). CNS-VS Memory was significantly correlated with the NAB Memory Index (r=.34), but only correlated with one individual memory test (Daily Living Memory Immediate Recall, r = .35). In general, this pattern of correlations suggests that the CNS-VS Memory domain is not measuring the same constructs as the NAB learning and memory tests.

CNS-VS Complex Attention was correlated with only one attention test (Numbers & Letters Part C Efficiency, r=.42). CNS-VS Cognitive Flexibility and CNS-VS Reaction Time were correlated with the NAB Attention Index (r=.39, r=.36, respectively) and three attention tests. CNS-VS Psychomotor Speed was correlated with the NAB Attention Index (r=.49), five attention tests, the NAB Memory Index (r=.58), and four memory tests.

The NAB Numbers & Letters (N&L) tests measure attention and speed of processing. The intercorrelations among these tests (Table 4) were small to medium. Similarly, the intercorrelations between CNS-VS domains measuring attention and speed, and the NAB N&L tests, were small to medium. This supports, to a modest degree, the concurrent validity of CNS-VS.

Table 3. Correlations Between NAB Tests and CNS-VS Neurocognitive Index and Domains.

	CNS Neuro-cognition Index Standard Score	CNS Memory Standard Score	CNS Psycho-motor Speed Standard Score	CNS Reaction Time Standard Score	CNS Complex Attention Standard Score	CNS Cognitive Flexibility Standard Score
Age (yrs)	-.026	-.250	-.030	-.205	.164	.003
Education (yrs)	.232	.133	.240	.223	.146	.166
RIST Index	**.414****	.211	**.298***	.212	.277	**.326***
WTAR Standard Score	**.325***	.267	**.359***	.069	.221	.206
Attention Index Standard Score	**.402****	.031	**.486****	**.361***	.167	**.393****
Memory Index Standard Score	**.369****	**.343***	**.580****	.251	.149	.248
Digits Forward T Score	-.056	.017	-.086	-.089	-.086	.007
Digits Backward T Score	.161	.138	**.297***	.094	.043	.173
Dots T Score	-.044	.144	.015	-.108	-.138	-.049
N&L Part A Speed T Score	**.304***	-.054	.152	**.385****	.105	**.314***
N&L Part A Errors T Score	.199	.119	**.320***	-.198	.273	.100
N&L Part B Efficiency T score	**.291***	-.176	**.426****	**.281***	.159	**.295***
N&L Part C Efficiency T score	**.515****	.112	**.408****	**.346***	**.416****	**.537****
N&L Part D Disruption T score	.191	.218	**.342***	.239	.033	.128
Driving Scenes T Score	.110	-.075	**.306***	.081	.026	.048
List Learning List A IR T score	.201	.166	**.440****	.185	.031	.112
List Learning List A Short DR T score	**.331***	.271	**.342***	**.364****	.124	.267
List Learning List A Long DR T score	**.385****	.265	**.426****	**.328***	.214	.276
Shape Learning Immediate Rec T score	.184	.239	.124	-.058	.134	.118
Shape Learning Delayed Rec T score	.056	.074	.078	.030	.071	.001
Story Learning Phrase Unit IR T Score	.157	.115	**.398****	.069	-.039	.123
Story Learning Phrase Unit DR T score	.119	.109	**.434****	-.019	-.055	.021
Daily Living Memory IR T score	**.301***	**.350***	**.437****	**.322***	.062	.197
Daily Living Memory DR T Score	.223	.268	**.541****	.127	.135	.123
Visual Discrimination T Score	.044	.148	.056	.124	.053	.003
Design Construction T Score	-.088	-.049	.006	.221	-.184	-.126
Mazes T Score	-.109	-.196	.147	-.049	-.142	-.117
Categories T Score	.262	.112	.205	.262	.163	.178
Word Generation T Score	.184	.073	.125	.193	.123	.114

Table Note: Bolded correlations are significant; *=p<.05; ** p<.01.

Table 4. NAB Tests Intercorrelation Matrix.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	18	17	19	20	21	22	23	24	25	26	27
1	RIST Index	--																										
2	WTAR	.699**	--																									
3	Attention Index	.398**	.225	--																								
4	Memory Index	.340*	.375**	.546**	--																							
5	Digits Forward	.356*	.259	.338*	.214	--																						
6	Digits Backward	.277	.180	.486**	.481**	.428**	--																					
7	Dots T Score	.146	-.035	.296*	.087	.124	.150	--																				
8	N&L Part A Speed	.140	.091	.563**	.036	-.080	.074	.095	--																			
9	N&L Part A Errors	-.044	.152	-.083	.259	-.031	.043	-.079	-.380**	--																		
10	N&L Part B Eff.	.043	-.017	.708**	.369**	.048	.203	.019	.447**	.164	--																	
11	N&L Part C Eff.	.228	.171	.696**	.462**	.075	.241	-.004	.296*	-.067	.483**	--																
12	N&L Part D Dis.	.361*	.208	.251	.334*	.119	.115	.154	-.302*	-.095	.079	.387**	--															
13	Driving Scenes	.167	.095	.548**	.350*	.028	-.020	.080	.174	.101	.297*	.337*	.036	--														
14	List Learning IR	.182	.255	.468**	.825**	.207	.340*	.080	.123	.094	.346*	.391**	.249	.198	--													
15	LL Short DR	.091	.194	.336*	.731**	.103	.289*	-.069	.169	-.004	.181	.359*	.187	.137	.610**	--												
16	LL Long DR	.172	.259	.432**	.763**	.157	.358*	-.005	.094	.168	.245	.432**	.262	.213	.657**	.790**	--											
17	Shape Learn. IRec.	.218	.282*	.231	.363**	.000	.075	.264	-.018	.213	.194	.173	.268	.172	.181	.028	.224	--										
18	Shape Learn. DRec.	.284*	.334*	.242	.512**	.197	.076	.045	-.005	.121	.233	.198	.300*	.122	.466**	.269	.314*	.617**	--									
19	Story Learning IR	.428**	.320*	.511**	.596**	.262	.501**	.182	.079	-.004	.394**	.414**	.338*	.101	.469**	.264	.210	.165	.217	--								
20	Story Learning DR	.283*	.258	.401**	.586**	.108	.391**	.199	.059	.190	.297*	.242	.109	.300*	.401**	.295*	.215	.186	.101	.654**	--							
21	DLM. IR	.432**	.341*	.324*	.688**	.290*	.398**	.063	-.098	.248	.126	.120	.232	.330*	.446**	.408**	.437**	.113	.174	.341*	.330*	--						
22	DLM DR	-.104	-.008	.191	.589**	-.075	.186	-.110	-.147	.441**	.173	.197	-.015	.448**	.432**	.373**	.375**	-.055	.055	.101	.283*	.551**	--					
23	Visual Discrim.	.168	.222	.030	.283*	.013	.119	-.107	-.018	.033	.084	.090	.091	-.152	.311*	.104	.129	.233	.374**	.204	.072	.150	.164	--				
24	Design Cons.	.287*	.111	.349*	.275	.236	.202	.172	.140	-.261	.312*	.136	.279*	.126	.287*	.085	.188	.258	.303*	.356*	.138	.178	-.069	.443**	--			
25	Mazes	.091	.082	.438**	.205	-.047	.130	.335*	.129	-.007	.457**	.218	.126	.351*	.249	-.029	.061	.249	.190	.276	.099	.101	.086	.223	.401**	--		
26	Categories	.375**	.349*	.464**	.426**	.153	.170	.065	.182	.091	.419**	.484**	.198	.224	.396**	.144	.284*	.325*	.360*	.366**	.153	.304*	.132	.352*	.458**	.454**	--	
27	Word Generation	.292*	.273	.379**	.410**	.161	.141	.280*	.159	.154	.258	.297*	.016	.270	.353*	.096	.226	.554**	.508**	.251	.441**	.075	.110	.283*	.308*	.142	.474**	--

Table Note: Bolded correlations are significant; *=p<.05; ** p<.01.

Table 5. CNS-VS Intercorrelation Matrix.

	Neuro-cognition Index Standard Score	Memory Standard Score	Psycho-motor Speed Standard Score	Reaction Time Standard Score	Complex Attention Standard Score	Cognitive Flexibility Standard Score
Neurocognition Index Standard Score	--					
Memory Standard Score	**.530****	--				
Psychomotor Speed Standard Score	**.545****	**.330***	--			
Reaction Time Standard Score	**.432****	.244	**.301***	--		
Complex Attention Standard Score	**.835****	**.291***	.216	.120	--	
Cognitive Flexibility Standard Score	**.943****	**.387****	**.385****	**.343***	**.855****	--

Table Note: Bolded correlations are significant; *=p<.05; ** p<.01.

Discussion: Overall, the CNS-VS domain scores were positively correlated with several traditional tests assumed to measure similar constructs. There were both expected and unexpected significant correlations between computerized and traditional testing. CNS-VS Psychomotor Speed was correlated with over half of the NAB domain and subtest scores and showed the strongest correlations with traditional tests. The data from the current study are consistent with previous studies generally reporting small to medium correlations between computerized and traditional neuropsychological test measures in healthy adults or athletes (Allen & Gfeller, 2011; Bleiberg, Kane, Reeves, Garmoe, & Halpern, 2000; Collie et al., 2003; Gualtieri & Johnson, 2006; Maerlender et al., 2010) and with patients with neuropsychiatric disorders (Gualtieri & Johnson, 2006).

In general, it is very difficult to interpret patterns of correlations between neuropsychological tests. In test manuals, these patterns of correlations are sometimes "expected" and they "make sense," but often they are unexpected and perplexing. Two tests can be correlated because they measure the same cognitive construct (e.g., processing speed), because they are both correlated with another underlying construct (e.g., intelligence or "g"), or for both reasons. Moreover, tests can be correlated in clinical samples because the clinical condition has a similar adverse effect on both cognitive domains. For example, traumatic brain injuries might affect peoples' speed of processing and memory in an adverse way—and a linear adverse effect on tests measuring these constructs might actually slightly increase the correlation between these tests. Therefore, there can be several reasons why we see both "expected" and "unexpected" patterns of correlations among tests.

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