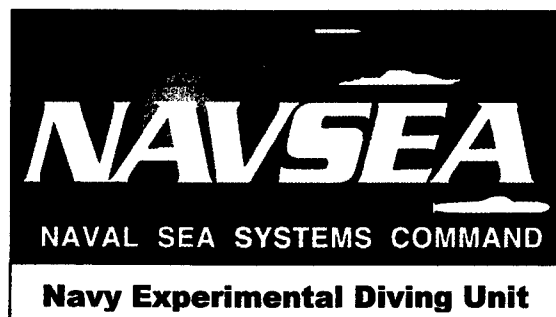


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Psychometric Evaluation of the Mindstreams Neuropsychological Screening Tool



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19. ABSTRACT This study explored the psychometric properties of the Mindstreams neuropsychological assessment. Twenty-one subjects completed baseline measures as well as three postdive assessments, each occurring after dives of 130, 150, and 190 feet of seawater (FSW). Results demonstrated good coefficients of stability and equivalence. Little learning effect was demonstrated over three assessments. More work on clinical use of the measure for cognitive changes due to cerebral decompression illness needs to be completed. Mindstreams does appear to be an option for neuropsychological screening when evaluation of cognitive functioning is necessary.				
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INTRODUCTION

Cognitive changes detected by neuropsychological assessments have been reported to occur in association with Type II cerebral decompression sickness (DCS).¹ However, the extent to which such changes might have been accrued or attenuated by stresses of diving that are not associated with the occurrence of DCS have not been shown. The purpose of this study is to assess the properties of a neuropsychological assessment to measure these cognitive changes.

Although results of neuropsychological tests may prove useful in diagnosing cerebral DCS, the administration of such tests and the interpretation of their results are problematic.^{2,3} First, the need for control or "baseline" results requires multiple administrations of a test to a given diver, a requirement that invites potential confounding of postdive results by a learning artifact. Administering different forms of the test each time it is taken often mitigates such artifacts, but this solution is cumbersome, and the reliabilities of the alternate forms are often not equally as accepted or established. Second, any testing for use in the context of DCS diagnosis must be completed on the dive or treatment site, and it must be brief, competently administered, and scored by minimally trained psychometrists or a computer. Traditional neuropsychological tests do not meet these requirements. For example, the traditional Halstead-Reitan Neuropsychological Battery requires two days to administer, while shorter batteries may take up to four hours to administer. The Automated Neuropsychological Assessment Measure (ANAM) is a computerized neuropsychological screening test that was developed to meet the requirements while still allowing cognitive function changes arising from traumatic brain injuries, strokes, and other accidents to be assessed in both military and civilian populations.⁴ The ANAM has demonstrated good reliability and construct validity evidence in these applications, but it lacks alternative forms for use in minimizing influences of learning artifacts across multiple test administrations. The ANAM also does not offer a clinical interpretive report, and it can be administered only after it has been installed on a local computer system.

One possible solution to such problems is in the Mindstreams' computerized neuropsychological assessment, a commercially available neuropsychological screening measure developed by NeuroTrax Corporation (New York, NY).⁵ The Mindstreams battery assesses performance across an array of cognitive domains including memory, executive function, visual-spatial perception, verbal function, attention, information processing speed, and motor skills. The Mindstreams battery demonstrates good construct validity evidence — i.e., good correspondence between its results and those of traditional neuropsychological tests that ostensibly measure similar cognitive domains. The Mindstreams tests were developed to minimize learning artifact in repeat testing, and they have good test-retest reliability.⁵ Furthermore, the Mindstreams assessment can be downloaded (with permission), administered, and scored over the Internet by trained personnel.

METHODS

PARTICIPANTS

This study was undertaken under Annex B for the test protocol, *Empirical Evaluation of Extensions to Air Diving No-Stop Limits*.⁷ Twenty-one diver-participants completed a baseline and the dives outlined in the protocol. Twenty-seven subjects completed the three dive profiles but did not complete the required baseline. Volunteers were required to read and sign the appropriate consent on the protocol Consent Form (Annex E of the main protocol). Divers were allowed to decline to participate in this Annex without surrendering their abilities to participate in the main protocol.

EQUIPMENT AND INSTRUMENTATION

Four testing stations, each consisting of a laptop computer with an operating version of the Mindstreams software, were set up in the Navy Experimental Diving Unit (NEDU) Environmental Physiology Laboratory (EPL) to support simultaneous administration of the Mindstreams battery for up to four different divers.

TESTING PROCEDURES

Each diver-subject completed a Mindstreams assessment after only one dive on each test schedule in the protocol in any order. Moreover, diver-subjects were allowed to complete a Mindstreams assessment after dives in any order on the different schedules. During each pre-dive brief the Principal Investigator (PI) scheduled post-dive testing for dive team divers who had not yet completed an assessment after a dive on the planned schedule.

Diver-subjects who had not completed a non-diving baseline Mindstreams assessment did so between three and seven days after last surfacing from a dive. Diver-subjects scheduled to take a post-dive Mindstreams assessment completed it between 30 and 45 minutes after surfacing. To dampen acoustic distractions from the environment, divers wore ear protection while completing the assessment. Testing took approximately 30 minutes to complete.

EXPERIMENTAL DESIGN AND ANALYSIS

Results were analyzed with a multivariate repeated measures design to test whether results under any of the four different conditions — pre-diving, post-130 feet of seawater (FSW), post-150 FSW, and post-190 FSW (if the trial advanced to this latter test schedule) — were significantly different from the overall mean result at a 95% confidence level. The test of significance under this design was made on the f statistic, a normalized overall measure of result differences from the overall mean. The f or “effect size”⁸ for independent samples ANOVA was corrected for test-retest dependence in the repeated measures design with use of the correlation r between results of successive tests ($f_{\text{corrected}} = f / \sqrt{1-r}$).⁹ This correction was made with $r = 0.5$, the lowest test-retest correlation of the seven index scores that constitute the

Mindstreams cognitive function assessment. The power of the test — i.e., the probability of detecting a minimum f , if it in fact exists — was estimated by using tables in Cohen.⁸ Complete results from twenty-seven different diver-subjects were required to achieve an 80% probability (power) of detecting an actual corrected effect size of 0.37 at 95% confidence. Of course, the power of this trial increases as the number of diver-subjects increases.

RESULTS

Mean, standard deviations, and sample sizes are presented in Table 1. Wilk's Lambda (Λ) is defined as the generalized variance for a set of variables. In this instance, the variables are the repeated measure of each Mindstreams subtest over four specific conditions: baseline, 130 FSW, 150 FSW, and 190 FSW. The Λ statistic neatly characterizes the within and total variability in terms of a single number between 0 and 1. The 0 represents group means that are different, and numbers closer to 1 than to 0 represent means that are similar. Table 2 presents the Λ , the corresponding f statistic, and the significance levels of each subtest. Only one subtest, that of visual-spatial processing, had a corresponding Λ that was significant at the 0.05 level. Reviewing the mean scores demonstrates an improvement of functioning across depths until the 190 FSW profile, when the mean score returns to the baseline performance. However, it should be noted that the diver population consistently scored greater than average (100), and the upper bounds of the confidence intervals were consistently a full standard deviation above the population parameters. Figures 1 through 8 graph the mean and 95% confidence intervals for the eight subtest scores. All figures are presented in the same format, with values ranging from 85 to 115. This range corresponds with the interpretation of the standardized scores of a mean of 100 and a standard deviation of 15. It is important to note that all means fall within this range, and all but one of the assessments fell within this range.

Test-Retest Reliability and Alternative Forms

Due to the design of this study, participants completed each of the assessments following different dive profiles. In other words, unless the profile was a repeated one the divers completed the exam after they had completed a set dive profile, regardless of prior dive conditions. To assess for the effect of learning on trials, we completed a repeated measures multivariate analysis. However, this analysis used test sequence instead of dive profile as its independent variable. The results are presented in Table 3. Figures 9 through 16 demonstrate the graphical representations as well as the 95% confidence intervals for each subtest. Information processing demonstrated the smallest Wilk's Λ (0.54), suggesting a significant linear increase in test scores over three trials, an increase shown in Figure 13. Similarly, global cognitive functioning and verbal functioning demonstrated significant Wilk's Λ values of 0.69, also suggesting a significant linear increase over trials (as shown in Figures 12 and 16).

The Mindstreams Neurotrax assessment uses three different forms for repeated trials. For the first three times a subject is administered the exam, he is presented with a new form (1, 2, and 3). After the third trial, the forms are then readministered in the same order. The correlation coefficient between two sets of tests scores can be computed by using Pearson product moment correlation and is called a coefficient of equivalence. These correlations are presented in Table 3 and denoted by the comparisons between form scores (1 X 2, 1 X 3, and 2 X 3). Test-retest reliability is an estimate of the stability of test scores and the variability of true scores. This coefficient of stability is also estimated by using the Pearson product moment statistic. Results are presented in Table 3 in the 1 X 1 column. Though no strict rules exist, both coefficients of stability and equivalence should range from 0.70 to 0.99. As seen in Table 3, the coefficients all range from 0.50 to 0.99. Overall, the measures appear to demonstrate acceptable test-retest reliability coefficients as well as the alternate-form reliability coefficients.

Table 4 reports the multitrait, multimethod validity coefficient matrix. Alternate forms reliability coefficients can be found on the diagonals in bold and italicized fonts, while the convergent validity coefficients can be found on the diagonals in bold alone. The discriminant validity coefficients are the correlations between measures of different constructs using the same method of measurement (noted in Table 4 by light gray) or the correlations between different constructs using different measurement methods (noted in Table 4 by the dark gray). Ideally, the correlations in light and dark gray should be substantially lower in value than the corresponding convergent validity coefficients. In Table 4, however, we see that most of the convergent validity coefficients are higher in value than the discriminant validity coefficients. The global cognitive scale appears to correlate highly with, and at times appears higher than, the demonstrated convergent coefficients. Overall, results suggest evidence for both convergent and discriminant validity. That being said, additional research such as structural equation modeling or confirmatory factor analysis needs to be conducted to verify the constructs.

Table 1.

Mindstreams Postdive Descriptive Statistics for Each Subtest by
Dive Profile

Mindstreams Subtest	Test Condition	Mean	Standard Error	95% Confidence Interval	
				Lower	Upper
Memory	Baseline	101.355	4.491	92.436	110.273
	130 FSW	100.278	2.532	95.250	105.306
	150 FSW	102.309	2.509	97.326	107.292
	190 FSW	101.552	3.009	95.576	107.527
Executive Function	Baseline	107.623	3.361	100.949	114.296
	130 FSW	102.253	1.895	98.491	106.015
	150 FSW	103.657	1.878	99.929	107.386
	190 FSW	104.357	2.252	99.886	108.828
Visual-Spatial	Baseline	110.321	4.635	101.117	119.524
	130 FSW	109.282	2.613	104.093	114.470
	150 FSW	113.491	2.589	108.349	118.633
	190 FSW	110.493	3.105	104.327	116.659
Verbal Function	Baseline	104.773	4.958	94.927	114.618
	130 FSW	104.715	2.795	99.164	110.265
	150 FSW	108.490	2.770	102.989	113.991
	190 FSW	107.461	3.322	100.864	114.058
Attention	Baseline	105.061	3.149	98.807	111.314
	130 FSW	100.571	1.775	97.045	104.096
	150 FSW	101.628	1.759	98.134	105.121
	190 FSW	100.540	2.110	96.351	104.730
Information Processing	Baseline	101.363	3.611	94.191	108.534
	130 FSW	100.550	2.036	96.507	104.593
	150 FSW	102.220	2.018	98.213	106.227
	190 FSW	104.156	2.420	99.351	108.961
Motor Function	Baseline	111.433	3.414	104.653	118.213
	130 FSW	105.512	1.925	101.690	109.334
	150 FSW	105.912	1.908	102.123	109.700
	190 FSW	106.713	2.288	102.171	111.256
Global Cognitive Score	Baseline	105.990	2.791	100.448	111.531
	130 FSW	103.309	1.573	100.185	106.433
	150 FSW	105.387	1.559	102.291	108.483
	190 FSW	105.039	1.870	101.326	108.752

Table 2.

Multivariate Statistics for the Repeated Measures Design by Dive Profile

Mindstreams Subtest	Wilk's		Error		
	Λ	F	DF	DF	P-Level
Memory	0.88	0.80	3	18	0.51
Executive Functioning	0.97	0.17	3	17	0.92
Visual-Spatial	0.65	3.30	3	18	0.04
Verbal Functioning	0.70	2.52	3	18	0.09
Attention	0.92	0.49	3	18	0.69
Information Processing	0.72	2.38	3	18	0.10
Motor Functioning	0.84	1.12	3	17	0.37
Global Cognitive Scale	0.84	1.17	3	18	0.35

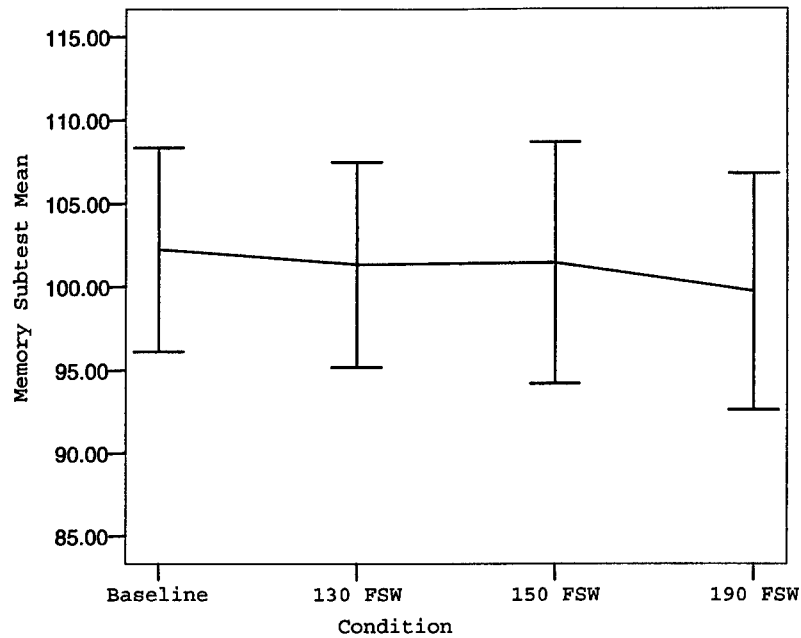


Figure 1. Mean and 95% Confidence Intervals for the memory subtests by dive profile.

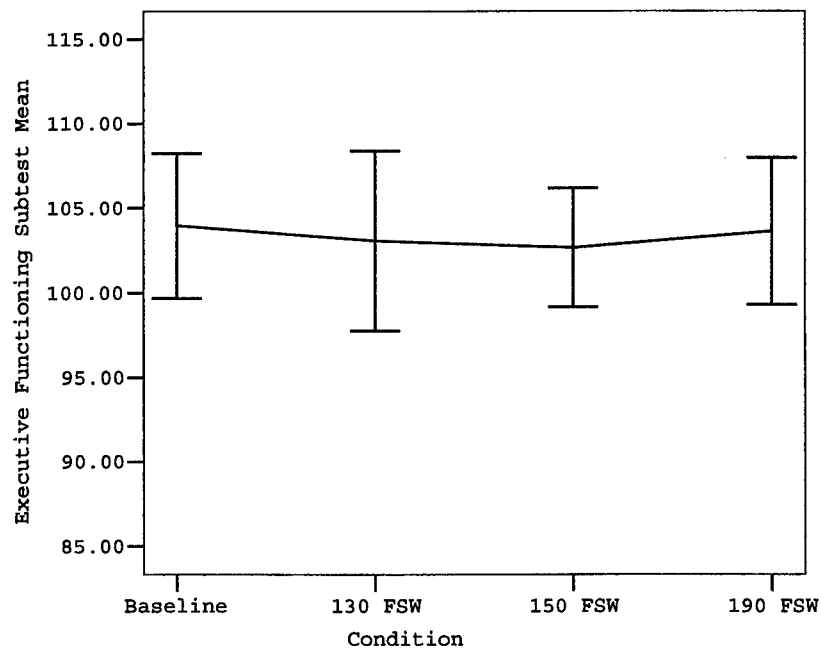


Figure 2. Mean and 95% Confidence Intervals for the executive functioning subtests by dive profile.

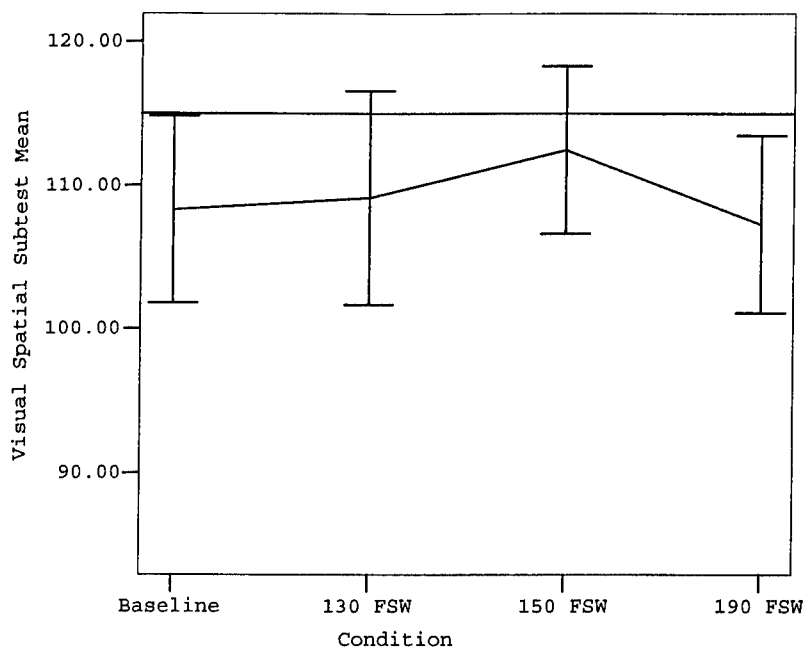


Figure 3. Mean and Confidence Intervals for the visual-spatial subtests by dive profile.

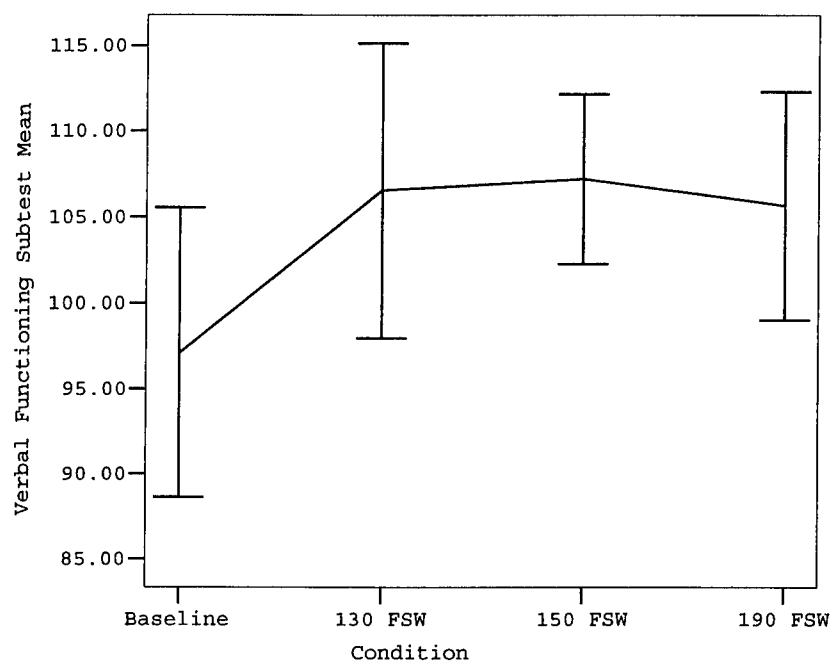


Figure 4. Mean and Confidence Intervals for the verbal functioning subtests by dive profile.

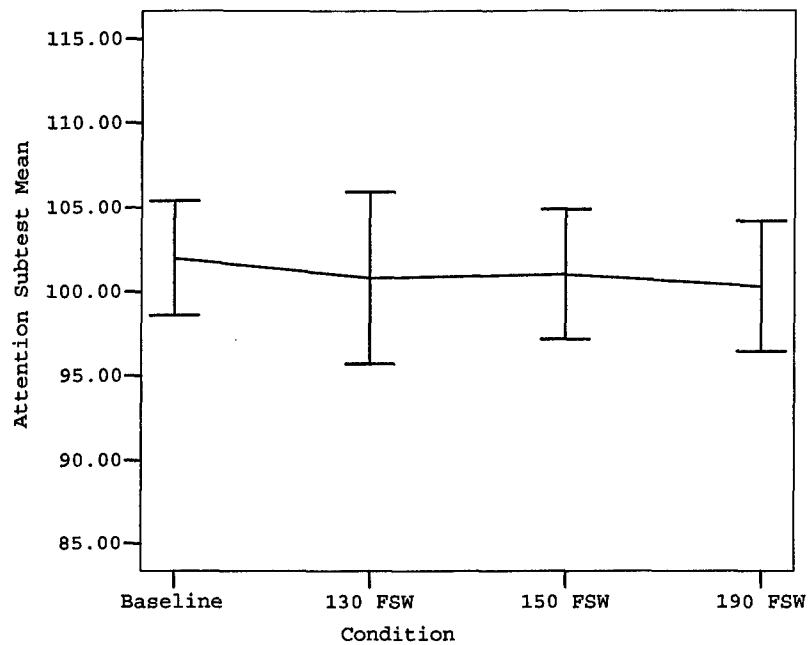


Figure 5. Mean and Confidence Intervals for the attention subtests by dive profile.

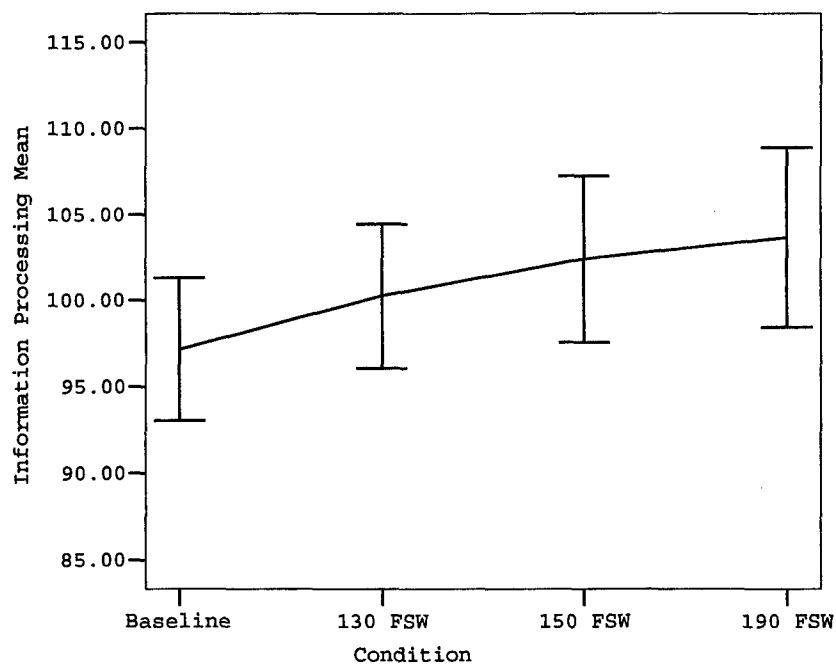


Figure 6. Mean and Confidence Intervals for the information processing subtests by dive profile.

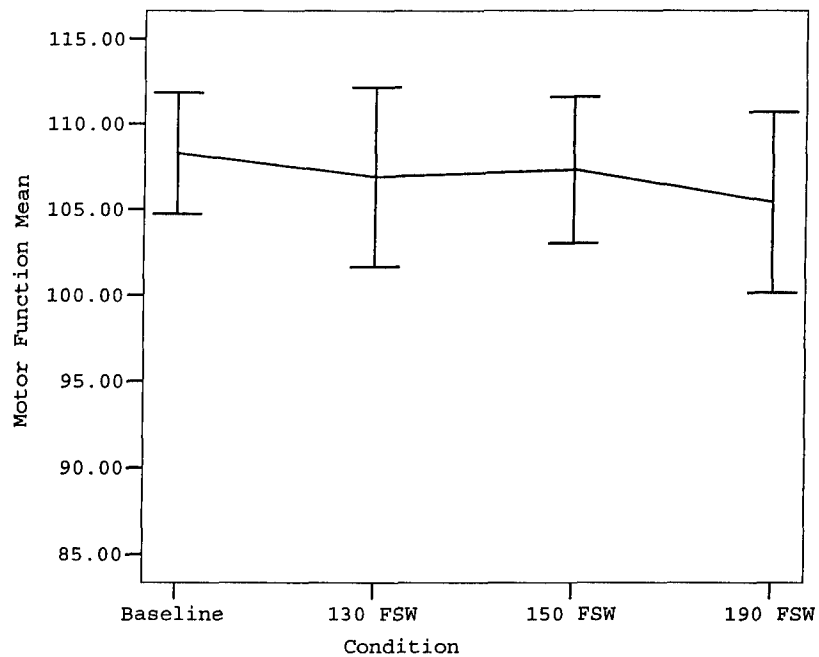


Figure 7. Mean and Confidence Intervals for the motor functioning subtests by dive profile.

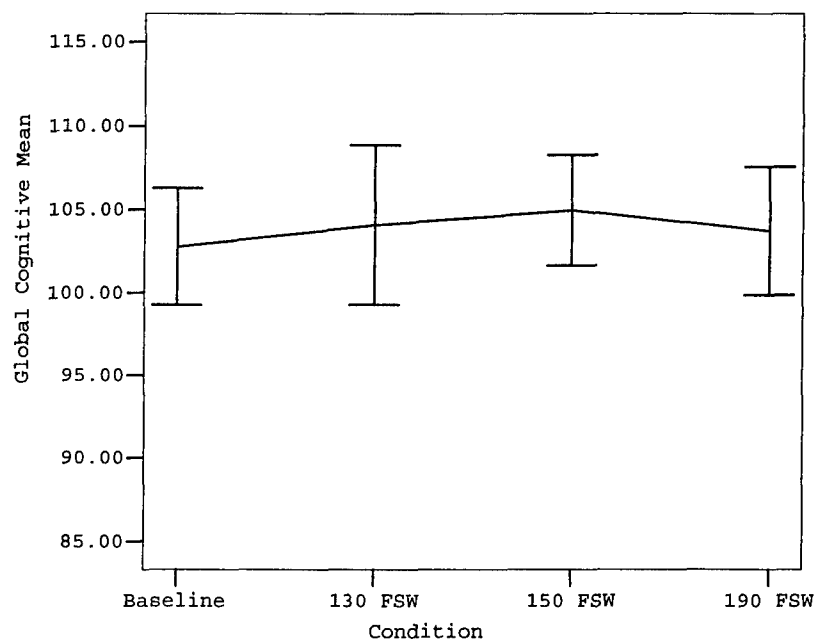


Figure 8. Mean and Confidence Intervals for the global cognitive functioning score by dive profile.

Table 3.

Multivariate Statistics and Pearson Product Moment Correlations
for the Repeated Measures Design by Assessment Sequence

Mindstreams Subtest	Wilk's		Error		p- value	Pearson's Correlation between Sequences			
	Λ	F	DF	DF		1 X 2	1 X 3	2 X 3	1 X 1
Memory	0.99	0.08	2	26	0.93	0.84	0.80	0.81	0.94
Executive									
Functioning	0.93	0.98	2	26	0.39	0.62	0.71	0.73	0.66
Visual-									
Spatial	0.93	0.99	2	25	0.39	0.83	0.68	0.71	0.72
Verbal									
Functioning	0.69	5.86	2	26	0.01	0.59	0.51	0.63	0.69
Attention	0.93	1.02	2	26	0.38	0.67	0.74	0.78	0.67
Information									
Processing	0.54	11.27	2	26	0.00	0.80	0.73	0.85	0.62
Motor									
Functioning	0.98	0.33	2	26	0.72	0.62	0.77	0.67	0.68
Global									
Cognitive									
Scale	0.69	5.73	2	26	0.01	0.89	0.92	0.92	0.92

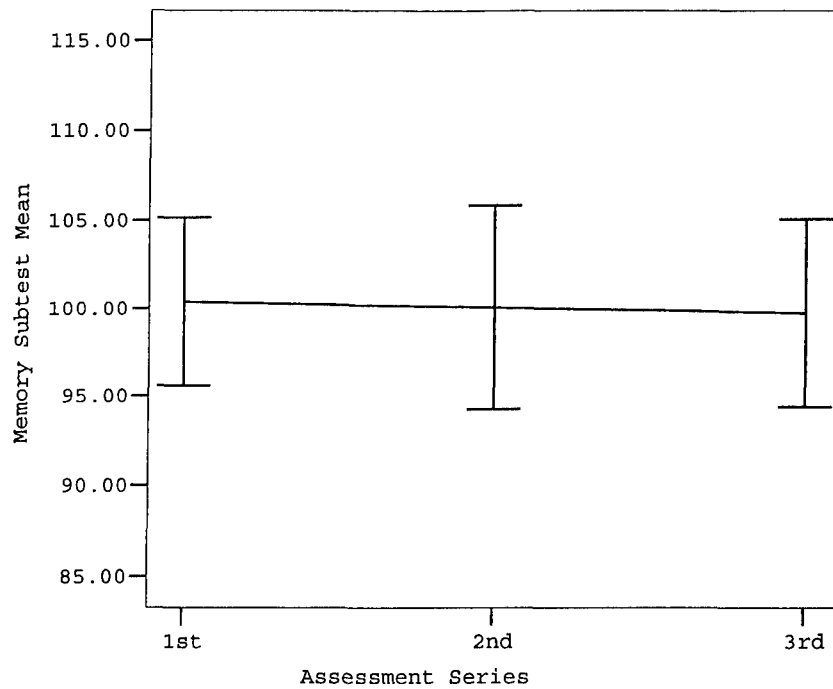


Figure 9. Mean and Confidence Intervals for the memory subtest by assessment timeline.

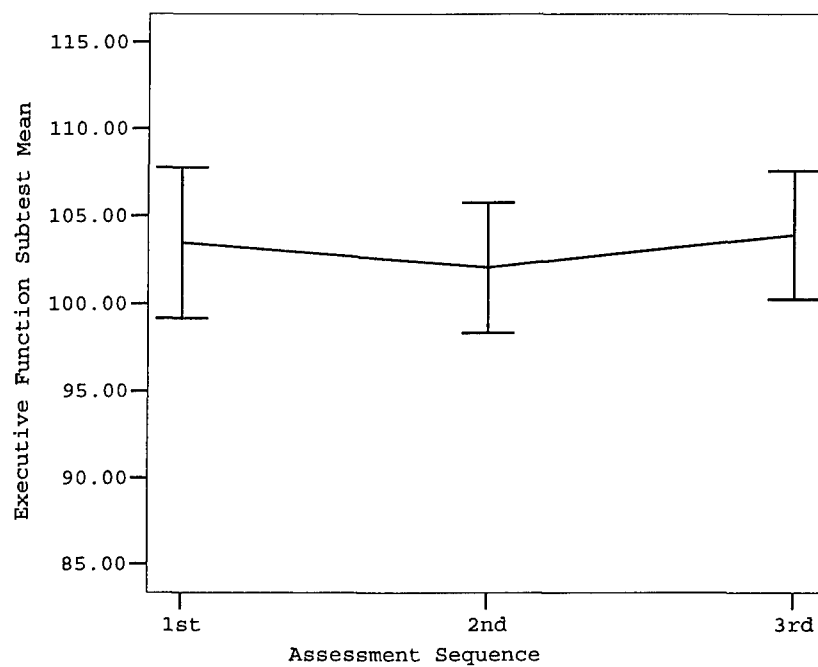


Figure 10. Mean and Confidence Intervals for the executive functioning subtest by assessment timeline.

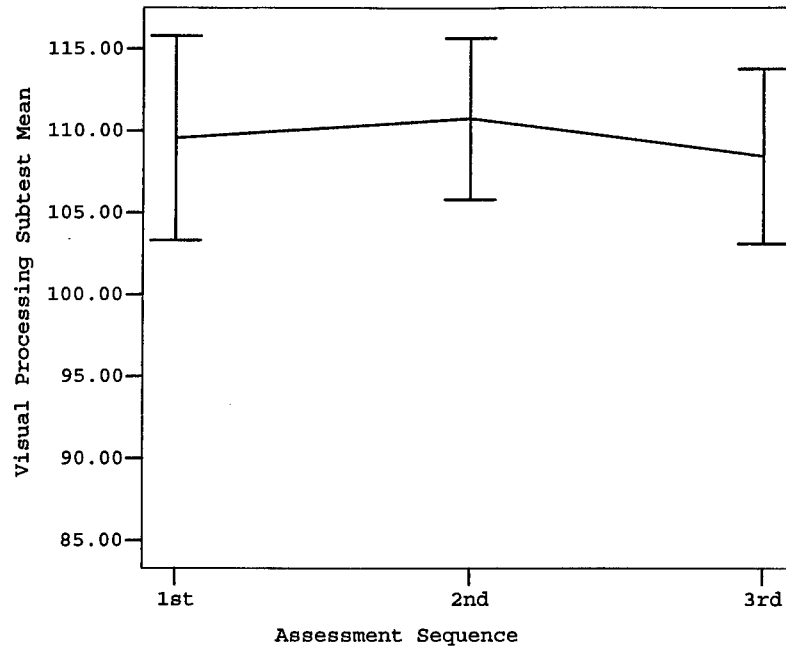


Figure 11. Mean and Confidence Intervals for the visual-spatial subtest by assessment timeline.

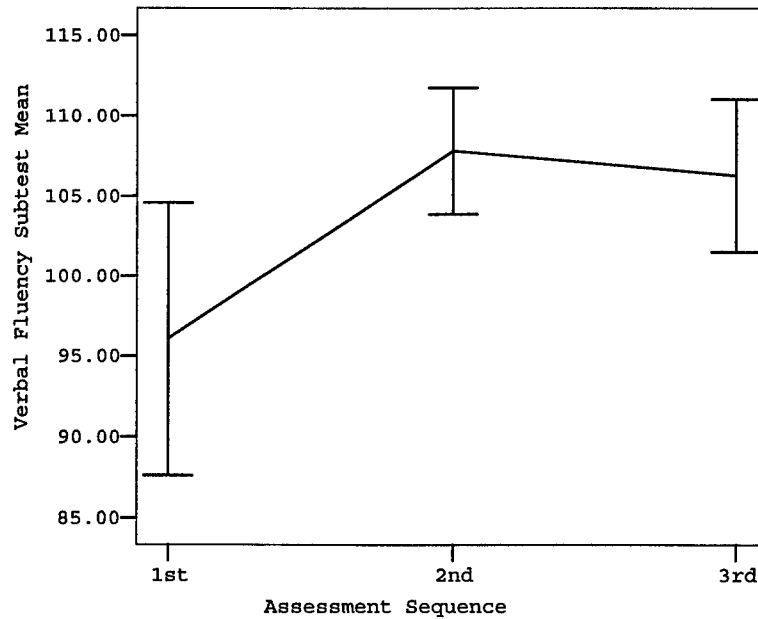


Figure 12. Mean and Confidence Intervals for the verbal fluency subtest by assessment timeline.

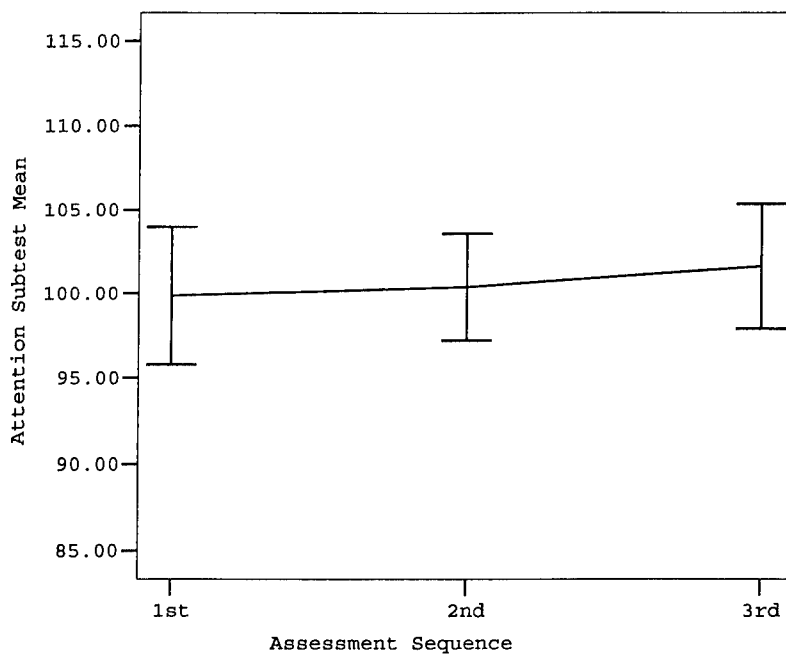


Figure 13. Mean and Confidence Intervals for the attention subtest by assessment timeline.

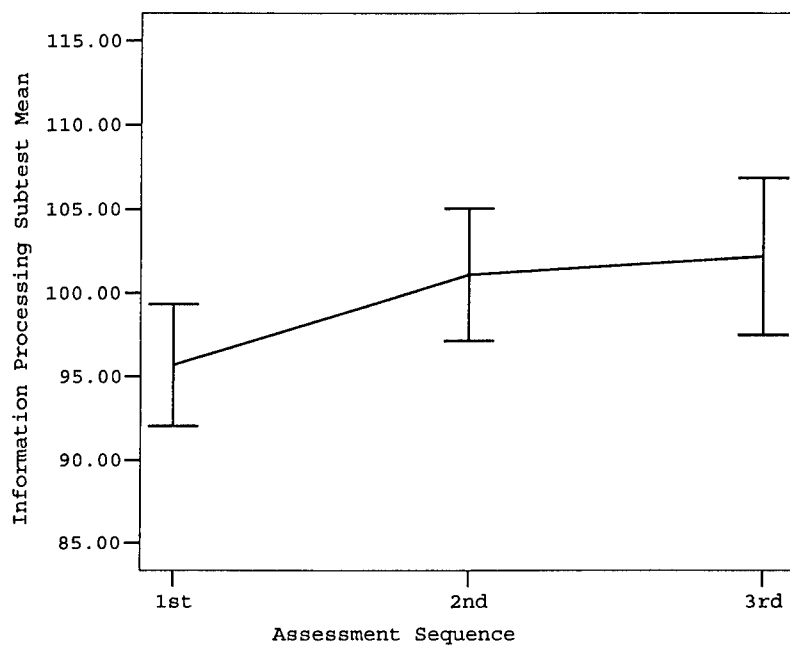


Figure 14. Mean and Confidence Intervals for the information processing subtest by assessment timeline.

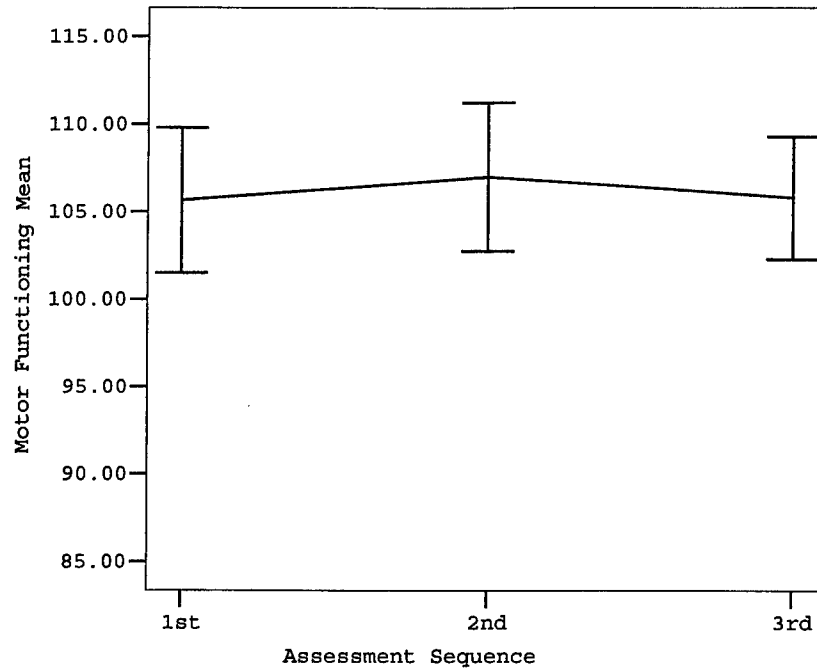


Figure 15. Mean and Confidence Intervals for the motor functioning subtest by assessment timeline.

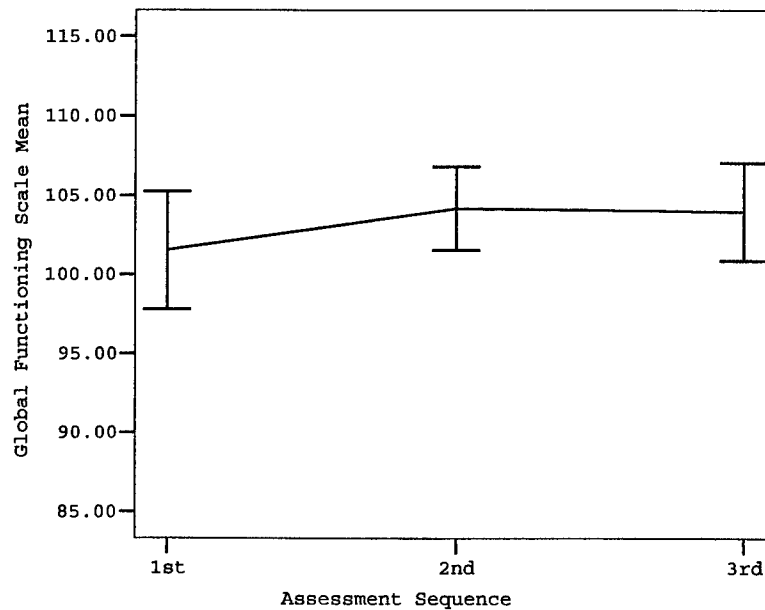


Figure 16. Mean and Confidence Intervals for the global cognitive functioning score by assessment timeline.

Time	Subtest	1a	2a	3a	4a	5a	6a	7a	8a	1b	2b	3b	4b	5b	6b	7b	8b
First	Memory (1a)	0.84															
	Executive Function (2a)	0.26	0.62														
	Visual-Spatial (3a)	0.64	0.50	0.83													
	Verbal Function (4a)	0.68	0.35	0.55	0.59												
	Attention (5a)	0.57	0.63	0.56	0.54	0.67											
	Information Processing (6a)	0.30	0.12	0.15	0.13	0.53	0.80										
	Motor Function (7a)	0.55	0.45	0.48	0.42	0.45	0.28	0.62									
	Global Cognitive Score (8a)	0.82	0.63	0.80	0.81	0.82	0.42	0.69	0.89								
	Memory (1a)	0.95	0.36	0.70	0.75	0.61	0.27	0.58	0.86	0.84							
	Executive Function (2b)	0.26	0.66	0.44	0.01	0.50	0.15	0.49	0.43	0.11	0.62						
Second	Visual-Spatial (3b)	0.77	0.58	0.72	0.67	0.62	0.24	0.75	0.85	0.77	0.28	0.83					
	Verbal Function (4b)	0.87	0.53	0.70	0.69	0.79	0.36	0.54	0.88	0.85	0.30	0.73	0.59				
	Attention (5b)	0.37	0.52	0.33	0.16	0.67	0.43	0.43	0.50	0.22	0.72	0.44	0.36	0.67			
	Information Processing (6b)	0.53	0.27	0.38	0.19	0.58	0.62	0.65	0.56	0.49	0.34	0.53	0.53	0.58	0.80		
	Motor Function (7b)	0.22	0.39	0.44	0.06	0.32	0.31	0.68	0.38	0.13	0.59	0.40	0.12	0.48	0.52	0.62	
	Global Cognitive Score (8b)	0.85	0.63	0.76	0.55	0.81	0.46	0.80	0.92	0.79	0.56	0.86	0.83	0.66	0.77	0.57	0.89
	**	Correlation is significant at the 0.01 level (2-tailed).															
	*	Correlation is significant at the 0.05 level (2-tailed).															
	Bold Italics	Coefficients of Equivalence															
	Bold	Coefficients of Stability															
	Light Grey	Multitrait Matrix															
	Dark Grey	Multimethod Matrix															

Table 4. Multimethod-Multitrait Correlation Matrix

DISCUSSION

The Mindstreams assessment has demonstrated clinical validity for measuring deficits incurred with Alzheimer's Disease, Parkinson's Disease, major head trauma, concussion, and attention deficit disorder. Overall, our study results suggest that the Mindstreams assessment has both convergent and discriminant validity in use with divers. The performance of diver-subjects was well within the norm standards of the measure, and the confidence interval for only one subtest exceeded the standard deviation expectations for the test. That being said, more research — such as item analysis structural equation modeling or confirmatory factor analysis — needs to be conducted to verify the constructs. Such methods add to the test's validity as a neuropsychological screening tool for divers by demonstrating the continuity of the factors as well as by presenting evidence for its predictive power.

In terms of measuring performance following dive protocols, we found no differences from baselines to posttest functioning. For the most part, results demonstrated consistent performance across all cognitive domains. No apparent neuropsychological impairment was demonstrated from performance during the Mindstreams assessment.

CONCLUSIONS

Mindstreams still appears to be an option for neuropsychological screening in diving subjects. However, a definitive answer to whether this assessment should be used in conjunction with diving and cerebral decompression relies on the measure's ability, or sensitivity, to detect changes in cognitive functioning when impairment occurs. This study did not attempt to gather clinical validity on the relationship between this measure and cognitive decompression illness. Until this study is completed, a definitive yes or no on the use of Mindstreams should not be made. Instead, the purpose was to explore the test parameters and construction. The Mindstreams assessment currently has three forms that demonstrate a good coefficient of equivalence: the forms seem to be relatively equal. This equivalence reduces the learning effect that can occur after repeated exposures, it allows for an increased accuracy in interpreting results, and it decreases the possibility of underestimating an actual impairment.

Mindstreams neuropsychological screening appears to be a psychometrically sound assessment. Though more research needs to be done on the item variance and neuropsychological constructs, the measure appears to have benefit for evaluating divers when suspected cognitive performance questions (e.g., following cerebral DCS, fatigue, or heat-related instances) arise.

Overall, Mindstreams was a simple-to-operate program that was easily administered to diver-subjects. They appeared to respond well to the program and engaged the tasks with much enthusiasm.

RECOMMENDATIONS

Further research — including some with diagnosed cerebral DCS — needs to be done on the clinical validity of the test. Also, work considering the use of the test for in-water performance needs to be done. This recommendation does not apply only to a tool such as Mindstreams. Few tests have norms for in-water performance.

Neuropsychology should continue to play a role in the evaluation and clinical treatment of cerebral decompression illness. The functional changes in diver's cognitive processes are too important to be overlooked, and neuropsychological assessment allows for monitoring, tracking, and reassurance that divers' cerebral functioning is improving or within expectations.

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