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EFFECTS OF RECREATIONAL DIVING ON ATTENTION: A Preliminary Study

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Key Words
Recreational diving, research, risk, safety.

Abstract

The neuropsychological functions of healthy recreational divers with varied cumulative diving experience and across repetitive dives have not been investigated. This preliminary study was conducted:
1 to determine attentional and concentrational levels in a group of healthy recreational divers,
2 to investigate the effects of years of diving experience on attentional and concentrational skills, and
3 to test the effects of repetitive recreational dives on attentional and concentrational levels.

The subjects consisted of 22 individuals aged between 16 to 71. The mean years of diving experience was eight years. A battery of Digit Span Forward, Digit Span Backward, and the Stroop Test was administered before and after the first and second dive on sport dive boats. Our results revealed that attentional and concentrational skills of healthy recreational divers generally fell within normal limits, were unrelated to years of cumulative diving experience, and were not compromised across repetitive recreational dives.

Introduction

Previous studies have not investigated attentional and concentrational skills in healthy recreational divers. In addition, there have been no studies examining effects of years of cumulative diving experience and repetitive dives on neuropsychological functioning levels.

Most diving studies have focused on divers who have suffered from decompression sickness (DCS). Results of these studies have been contradictory. Specifically, selective neuropsychological deficits have been identified in professional divers with focal neurological manifestations of DCS.[1-3] On the other hand, Andrews et al.[4] found no evidence of cognitive impairment in abalone divers who showed evidence of DCS. While measures assessing attentional and concentrational skills were not directly administered, these functions are important to examine since they underlie all cognitive skills. Intact attentional and concentrational skills are necessary for safe self-monitoring of diving protocols. Andrews et al. suggested that professional and recreational divers who follow the appropriate safety protocols should not be at risk for progressive brain damage resulting from diving.

Neuropsychological functioning has not been thoroughly investigated in recreational divers. For example, Levin et al.[5] reported on two divers who were administered limited neuropsychological tests and neuroradiological examinations within the first month of sustaining DCS. These patients had negative medical and psychiatric histories before their episodes of DCS. Magnetic resonance imaging (MRI) results revealed paraventricular and subcortical white matter lesions in both patients. The neuropsychological screening indicated compromises across measures sensitive to information processing skills, visual-motor skills and selective verbal

memory skills, as well as verbal and non-verbal fluency skills. The potential negative effects of depression and anxiety on cognitive skills were not fully considered.

Levin and colleagues were uncertain as to whether the MRI findings reflected the DCS injuries or the combined effects of acute illness, cumulative diving experience, or other cerebral insults.[5] They suggested that neuropsychological testing and serial MRIs be performed on a control group of divers without DCS in order to differentiate injury effects from chronic diving-related neurological insults. It is unknown whether there are chronic diving-related neurological insults in divers without evidence of DCS.

This study was designed to determine whether attentional and concentrational skills, foundational components of all cognitive skills, are compromised in healthy recreational divers with varied years of cumulative diving experience and across repetitive dives. It is hypothesised that attentional and concentrational skills of healthy recreational divers are within normal limits, are unrelated to cumulative diving experience, and are not compromised across repetitive dives.

Methods

SUBJECTS

The subjects consisted of 22 healthy, right-handed adult divers recruited from sport diving boats. Criteria for exclusion included a self-reported history of:

1 diving accidents,
2 psychiatric disorder,
3 learning disability,
4 epilepsy,
5 asthma within the past five years,
6 unresolved syncopal episodes,
7 chronic obstructive pulmonary disease,
8 spontaneous pneumothorax,
9 myocardial infarct within one year,
10 significant arrhythmia,
11 insulin-dependent diabetes,
12 demyelinating disease,
13 or substance use or abuse.

All subjects signed statements that they had not consumed a controlled substance nor alcohol for at least 24 hours before the testing. All subjects who answered "yes" on any of the above criteria were excluded from the study. All subjects reported no evidence of remarkable ongoing pathology with respect to ears, eyes, nose and throat, cardiovascular, respiratory, gastrointestinal, neurologic, or psychological systems. None of the female subjects indicated that they were pregnant. The demographic and diving parameters of the study group are shown in Table 1.

TABLE 1
DEMOGRAPHICS AND DIVING PARAMETERS OF SUBJECTS

Characteristic or Parameter	N	Mean	(±SD)	Range
Number of subjects	22			
Gender				
Male	14			
Female	8			
Education (years)		15.4	(±2.7)	10-22
Age at testing (years)		35.3	(±12.5)	16-71
Diving experience (years)		8.0	(±7.3)	1-26
Dive time dive 1 (minutes)		41.0	(±11.2)	24-69
Dive time dive 2 (minutes)		38.7	(±12.1)	9-68
Depth of dive 1 (m)		12.7	(±3.8)	8.2-18.2
Depth of dive 2 (m)		15.2	(±2.8)	10.4-19.8

INSTRUMENTS

A history and demographic questionnaire was used to determine if the subjects met the criteria for inclusion in the study. Five neuropsychological tests, sensitive to brief and sustained attentional and concentrational skills, were administered before and after the initial dive (dive 1) and after the second dive (dive 2).

The tests administered specifically assess attentional and concentrational skills. Digit Span is sensitive to general brain dysfunction and is considered a classic measure of attention.[6,7] The Digit Span Forward test taps passive and brief attentional and concentrational skills whereas the Digit Span Backward test relies on "working memory".[8,9] This latter task also involves double-tracking in that both the subject's memory and the reversal of the operation must work simultaneously. The Stroop Test is a selective executive systems measure that documents information processing speed, inhibition of habitual responses and the maintenance of a course of action despite visual distracters. The following cognitive measures were used:

1 Digit Span Forward: Digit Span Forward is a sub-test used in the Wechsler Adult Intelligence Scale – Revised .[9] The subject's task is to repeat two sequences of digits exactly as they are read by the examiner. When a sequence is repeated correctly, the examiner reads the next longer number sequence, continuing until the subject either fails a pair of same length number |sequences or repeats a nine-digit sequence correctly. The score utilised for this study is the maximum number of digits correctly repeated.

2 Digit Span Backward: Digit Span Backward is also a sub-test of the Wechsler Adult Intelligence Scale – Revised.[9] Digit Span Backward number sequences are two to eight digits long. The subject's task is to say a

sequence in reverse order after the examiner presents it. The test continues until the subject either fails a pair of same length sequences or correctly recalls eight digits in reverse order. The score utilised of this study is the maximum number of digits correctly repeated.

3 Stroop Test:[10] The test contains three parts. First, the subject is asked to read a 100 word list of colour names (blue, red, and green) printed in black ink as rapidly as possible (Stroop A). Then, the subject is asked to name the colour of 100 coloured blocks of ink as rapidly as possible (Stroop B). Last, the subject is required to name the colour of the ink in which the work is printed as rapidly as possible (Stroop C). This latter sub-test of the Stroop is the "interference" sub-test since the words are colour names printed in ink of a different colour (e.g., the word "green" is printed in red ink and the correct answer is "red"). Each of the individual subtests is timed. The score is the time to complete each sub-test.

Procedures

All subjects were administered the demographic information sheet, Digit Span Forward, Digit Span Backward, and the three sub-sets of the Stroop Test prior to the first dive by two experienced test examiners (Predive). The tests were also administered after dive 1 and dive 2 (Post-dive 1 and Post-dive 2, respectively). Immediately after each dive, subjects indicated the depth and actual dive time. In addition, the surface interval time was recorded for all subjects. The depth and time figures were confirmed with the diving tables as originally recorded by the dive master aboard the dive boats.

Statistical analysis

Intercorrelations between the dependent neuropsychological measures and diving experience listed in Table 2 were obtained using Pearson product-moment correlation analysis to predict whether cumulative diving experience affects neuropsychological performance. Independent sample t-tests were performed on the dependent measures grouped by gender. One-way analysis of variance with repeated measures was performed to determine the effects of repetitive dives. One-way analysis of covariance with repeated measures was performed to determine the effects of repetitive dives while statistically controlling for effects of the correlated diving parameter.

Results

HYPOTHESIS 1

Attentional and concentrational skills of healthy divers are within normal limits.

Analysis of individual scores predive indicates that all subjects performed within normal limits on all measures with the exception of one subject whose Stroop B performance and two subjects whose Stroop C performances were impaired for their ages (Table 2).

HYPOTHESIS 2

Attentional and concentrational skills of healthy divers are unrelated to years of cumulative diving experience.

Of the five measures collected over three time frames, only Digit Span Forward Post-dive 2 and years of diving experience were significantly correlated ($r = +0.441$, $p = 0.040$). Therefore, in subsequent analyses of Digit Span Forward the effects of the covariate years of diving experience were statistically controlled.

HYPOTHESIS 3

Attentional and concentrational skills of healthy recreational divers are not compromised across repetitive dives.

TABLE 2
PEARSON PRODUCT-MOMENT CORRELATIONS AND PROBABILITIES BETWEEN YEARS OF DIVING EXPERIENCE AND NEUROPSYCHOLOGICAL MEASURES COLLECTED OVER THREE TIME FRAMES

Measure	Predive r (p-value)		Post Dive 1 r (p-value)		Post Dive 2 r (p-value)	
WAIS-R[9]						
Digit Span Forward	0.222	(ns)	-0.074	(ns)	0.441	(0.040)
Digit Span Backward	0.084	(ns)	0.232	(ns)	0.075	(ns)
Stroop[10]						
A	0.079	(ns)	0.268	(ns)	0.243	(ns)
B	-0.001	(ns)	0.045	(ns)	0.005	(ns)
C	-0.196	(ns)	-0.193	(ns)	-0.050	(ns)

TABLE 3

OVERALL ANOVA OR ANOCOV AND SPECIFIC COMPARISON RESULTS OF NEUROPSYCHOLOGICAL TEST PERFORMANCE ON REPEATED TESTING

	Overall ANOVA or ANOCOV			Specific Comparison ANOVA or ANOCOV								
				Predive v Post Dive 1			Predive v Post Dive 2			Post Dive 1 v Post Dive 2		
Measure	**F**	**df**	**P**	**F**	**df**	**P**	**F**	**df**	**P**	**F**	**df**	**P**
WAIS-R[9]												
Digit Span Forward*	2.85	2,40	0.07	4.53	1,20	0.046	5.63	1,20	0.028	0.25	1,20	ns
Digit Span Back	2.22	2,42	ns	—	—	—	—	—	—	—	—	—
Stroop[10]												
A	1.68	2,42	ns	—	—	—	—	—	—	—	—	—
B	5.40	2,42	0.008	6.96	1,21	0.015	7.12	1,21	0.014	0.10	1,21	ns
C	15.08	2,42	0.000	14.11	1,21	0.001	18.84	1,21	0.000	4.87	1,21	0.039

*The effects of years of diving experience were statistically removed in the analysis of Digit Span Forward.

Digit Span Forward and Digit Span Backward: Results of ANOVA and ANOCOV are shown in Table 3. One-way analysis of covariance with repeated measures controlling for diving experience revealed a trend for repetitive dive effects for Digit Span Forward [F (2, 40) = 2.85, P<0.07]. Specific comparisons showed that when diving experience was statistically controlled, subjects had lower Digit Span Forward scores Predive than Post Dive 1 and Post Dive 2 [F (1,20) = 4.53, P<0.046; F (1,20 = 5.63, P<0.028], respectively, as illustrated in Figure 1. Digit Span Backward was not significant overall across repetitive dives.

Stroop Test: Results of the statistical analyses of the three Stroop sub-tests are presented in Table 3. One-way analysis of variance with repeated measures showed no significant repetitive dive effect for Stroop A. However, significant repetitive dive effects for Stroop B and C were revealed with one-way analysis of variance with repeated measures [F (2, 42) = 5.40, P < 0.01; F (2,42) = 15.08, P < 0.0000]. Figure 2 shows that subjects had significantly faster times to completion for Stroop B and Stroop C for each progressive dive. Stroop B statistical results were: [Predive versus Post Dive 1: F (1,21) = 6.96, P < .015; Predive versus Post Dive 2: F (1,21) = 7.12, P < 0.014]. Stroop C statistical results were: [Predive versus Post Dive 1: F (1,21) = 14.11, P < 0.0001; Predive versus Post Dive 2: F (1,21) = 18.84, P < 0.000]; and [Post Dive 1 versus Post Dive 2: F (1,21) = 4.87, P < 0.039].

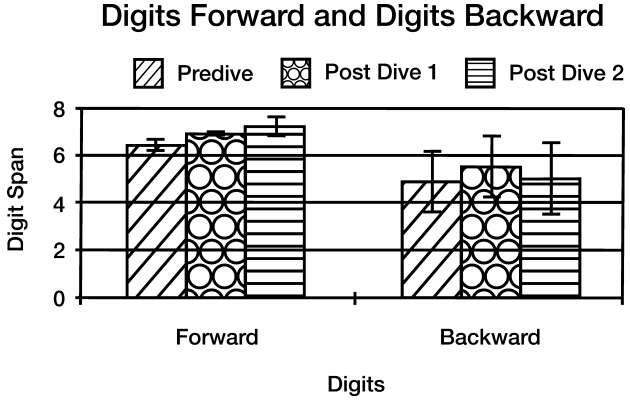

Figure 1. Adjusted means and standard deviations of Digit Span Forward and means and standard deviations of Digit Span Backward before and after two repetitive dives are illustrated. Performances on Digit Span Forward were adjusted for effects of diving experience.

Discussion

An earlier study noted the need to study the cognitive status of healthy divers in order to differentiate injury effects from chronic diving-related neurologic insults.[5] This investigation was designed to determine whether attentional and concentrational skills of healthy

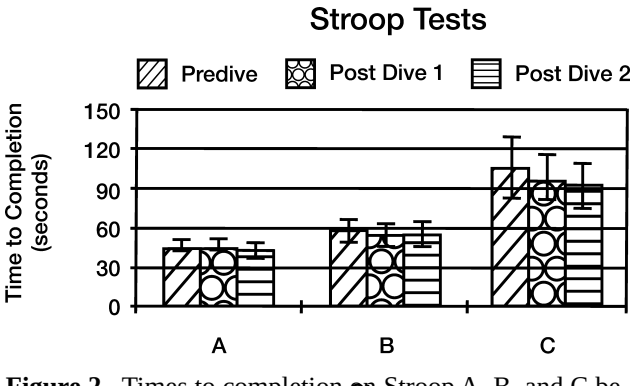

Figure 2. Times to completion on Stroop A, B, and C before and after two repetitive dives are shown. Means and standard deviations are plotted.

recreational divers fall within normal limits and whether these skills are compromised with varied years of cumulative diving experience and across repetitive dives.

Our findings indicate that most subjects performed within normal limits on measures sensitive to attentional and concentrational skills. While each of three subjects had one impaired score, more than 97% of all scores were within normal limits. Therefore, healthy recreational divers with varied years of diving experience generally had intact attentional and concentrational skills at baseline testing. In general, there was no relationship between cumulative diving experience and attentional and concentrational skills. However, there was a positive relationship between years of diving and one task tapping passive attentional and concentrational skills, Digits Forward Post Dive 2. The nature of this relationship is unclear, with further research needed to clarify the association.

The results also revealed that test scores were intact across repetitive dives. Specifically, measures tapping brief attentional and concentrational skills and sustained attentional and concentrational skills with and without interference fell within normal limits. While these findings confirm the hypothesis, there were unanticipated results: subjects' performances improved on both sustained attentional and concentrational measures with and without interference (Stroop B and Stroop C) and on a selective brief attentional and concentrational measure (Digit Span Forward) across repetitive dives.

Such improvement on selective attentional measures is atypical given the task demand of each measure. One might expect factors such as overall practice effects to generalise to all measures. However, our subjects improved not only on the least demanding task in the battery (Digits Forward) but also on the most rigorous attentional measure (Stroop C). The fact that these measures and Stroop B significantly improved across repetitive dives while Digit Span Backward and Stroop A did not improve leads one to analyse the task demands of each measure. Digit Span Backward involves more than the attentional and concentrational demands of the other tasks. Specifically, Digit Span Backward involves working memory as well as attentional span. This task taps double-tracking skills, that is, both memory and the reversing operations must proceed simultaneously.[6] Such memory skills are less impacted by practice effects because each trial is unfamiliar. Most tests that are affected by practice are those that have a speed component and a single solution. Digit Span Backward does not. However, Stroop A is a speed sensitive test in which one would expect a practice effect. It is unclear why improvement over repetitive Stroop A testing was not observed.

The fact that repetitive diving does not adversely affect attentional and concentrational skills has significant implications for divers' ability to follow safety protocols. This implies that healthy recreational divers making two dives during the course of a day should be able to maintain the necessary attention and concentration to self-monitor their diving profiles.

Limitations of study and future research directions

1 While this was the first preliminary study reported in the literature looking at healthy recreational divers' attentional and concentrational skills, other cognitive functions such as intellectual level, language, motor, sensory-perceptual, constructional, visual perceptual, memory, planning, and organisational skills were not examined. In addition, psychiatric variables were not objectively measured. Further investigation of this population is needed to better understand these cognitive and social-emotional factors.

2 A non-diving control group was not tested. Control group comparisons would determine whether the unanticipated improvement in selective attentional and concentrational performance across repetitive testing could be explained by a practice effect rather than a repetitive diving effect.

3 A replication study with a larger sample size that includes healthy recreational divers with more years of diving experience and assessment of other cognitive functions would be an important addition to the current study. Such a study would aid in the development of a more comprehensive understanding of the possible negative effects of cumulative diving experience and unstressful repetitive diving among healthy recreational divers. The positive relationship between years of diving and selective attentional and attentional skills should be further investigated by such future research.

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SENSATION SEEKING PERSONALITY TRAITS OF RECREATIONAL SCUBA DIVERS

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Key words
Air, recreational diving, personality.

Abstract

Objectives
The sensation seeking personality traits of recreational scuba divers are poorly understood. This study aimed to use a validated measure to determine the extent to which divers' sensation seeking traits differ from the general population.

Methods
Thirty experienced recreational scuba divers were enrolled. Their sensation seeking traits, including thrill and adventure (TAS) and experience seeking (ES), disinhibition (DIS) and boredom susceptibility (BS), were assessed with the Sensation Seeking Scale, Form V.

Results
The divers scored significantly higher than the reference population on both the TAS and ES sub-scales ($p<0.001$ and $p=0.003$, respectively), and significantly lower ($p=0.010$) on the BS sub-scale. There was a trend for the divers to score lower on the DIS sub-scale ($p=0.076$). There was no difference between the divers and the reference population on "total" sensation seeking score ($p=0.511$).

Discussion
Divers in the study were thrill, adventure and experience seekers but not overall sensation seekers. The TAS and ES findings are consistent with the results of other studies of individuals who engage in risky sports. The DIS, BS and "total" score findings do not show this consistency and are attributed to the older age and more "establishment" personalities of our divers. Larger studies are required to further investigate diver sensation seeking and to compare subgroups within the diving population.

Introduction

In an extensive review of the role of personality in sports, Eysenck et al. concluded that those who engage in sports tend to be more extroverted than non-participants.[1] The relation between extroversion and sports is said to be mediated by narrower traits like sensation seeking, assertiveness, competitiveness, impulsiveness and high pain thresholds.[2]