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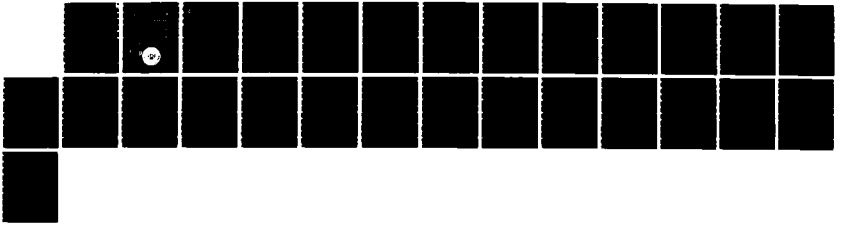

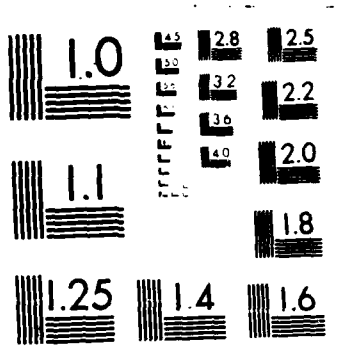

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NAVY EXPERIMENTAL DIVING UNIT
REPORT NO. 3-87

REPEATED MEASUREMENT OF DIVERS' WORD FLUENCY

By

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and

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DEPARTMENT OF THE NAVY
NAVY EXPERIMENTAL DIVING UNIT
PANAMA CITY, FLORIDA 32407-5001

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Word Fluency is an aspect of human behavior that can be a useful indicator of possible neurological effects of long, deep undersea diving, acute decompression sickness, and arterial gas embolism. Testing of divers' Word Fluency before, during, and after dives requires availability of multiple, equivalent but different tests of Word Fluency. This report describes the procedures used to develop and evaluate Word Fluency test forms suitable for repeated measurement experimental designs. Alternate, parallel forms of a Word Fluency test are recommended. Results are presented of illustrative measurements of Word Fluency before, during, and after 30-day saturation dives to simulated depths of 259m and 335m, and of follow-up measurements of a central nervous system decompression sickness case. These results indicate that a Word Fluency test could be a sensitive indicator of environmental stress. Normative data for divers using several letters are presented.

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ABSTRACT

Word Fluency is an aspect of human behavior that can be a useful indicator of possible neurological effects of long, deep undersea diving, acute decompression sickness, and arterial gas embolism. Testing of divers' Word Fluency before, during, and after dives requires availability of multiple, equivalent but different tests of Word Fluency. This report describes the procedures used to develop and evaluate Word Fluency test forms suitable for repeated measurement experimental designs. Alternate, parallel forms of a Word Fluency test are recommended. Results are presented of illustrative measurements of Word Fluency before, during, and after 30-day saturation dives to simulated depths of 259m and 335m, and of follow-up measurements of a central nervous system decompression sickness case. These results indicate that a Word Fluency test could be a sensitive indicator of environmental stress. Normative data for divers using several letters are presented.

KEY WORDS:
Word Fluency
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Diving
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Pyschology
NAVSEA Task #86-54
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REPEATED MEASUREMENT OF DIVERS' WORD FLUENCY

Deep prolonged saturation dives may have temporary or long-lasting effects on the health of military and industrial divers (Lewis & Baddeley, 1981). Concern for the welfare of divers should motivate attempts to identify any residual effects. Such attempts would have practical, useful outcomes: a basis for informed participation by divers, realistic appraisal of risks to be reflected in compensation of divers, and specification of dangers for which there may be preventive measures or adequate medical treatment.

One of the body systems that may be affected by diving is the central nervous system. The health status of this system can be assessed with neuropsychological tests. Several neuropsychological tests would be needed for a comprehensive assessment, and a wide variety of such tests are available reflecting different aspects of nervous system function (Fillskov & Boll, 1981). One type of test with clinical significance reflects Word Fluency (Borkowski, Benton & Spreen, 1967; Lezak, 1983). Word Fluency is "the facility to produce words that fit one or more structural, phonetic, or orthographic restrictions that are not relevant to the meaning of words" (Ekstrom, French, Harman, & Dermen, 1976). A recent review of Word Fluency literature can be found in Ekstrom, French, and Harman (1979).

Loss of Word Fluency is one of the most common aspects of aphasia. It is associated with many types of neurological insults; for example, stroke, toxic chemical exposure (Anger, 1984) and closed head injury (Borkowski et al, 1967). Word Fluency reflects mild linguistic deficits in expressive speech, which are among the most persistent effects of a variety of neurological disorders.

Word Fluency is different from other attributes involving verbal materials, such as Verbal Closure, Verbal Comprehension, Expressional Fluency, or Associational Fluency (Ekstrom et al, 1976, 1979). People who display a high degree of one of these will not necessarily exhibit the others. Word Fluency is one of the seven Primary Mental Abilities (Thurstone, 1938), and Word Fluency tests are predictive of communication skills (Taylor, Ghiselin, & Yagi, 1967). Although Word Fluency is not required to a large degree by U.S. Navy enlisted jobs in general, some of these jobs do call for extraordinary Word Fluency (Carter & Biersner, 1982). Tests of this ability include writing or saying words with particular beginning or ending sounds (Ekstrom et al, 1976, 1979). For instance, the Word Beginnings Test requests the subject to name as many words as he can think of (within generous time limits) that begin, for example, with the letter B.

Small sample sizes and the difficulty in controlling extraneous environmental variables necessitate repeated measurements of word fluency. To determine how diving affected a diver's Word Fluency, it is apparent that one has to measure a diver several times during a dive (or series of dives). Retesting with the same letter, B for instance, would not be reasonable

because the divers would become sensitive to B words, or even develop special mastery of these words so that the test would no longer reflect Word Fluency. A better procedure would be to use different letters on each occasion of testing. However, letters are not all equally evocative of words. For example, the letter S tends to evoke many more words than the letter Y. What is needed is a set of letters that all elicit approximately the same number of words (per unit of time) from divers. The letters should also have about the same variability among divers of the number of words produced. Furthermore, the divers with top and bottom and intermediate scores with one letter should retain their status with other letters. It would be convenient if scores on the test did not change appreciably with practice on the test. A test with these properties is suitable for repeated-measures experiments (Lord & Novick, 1968; Winer, 1971). The power of a repeated-measures experiment to show an effect depends upon individual differences that are large, relative to measurement errors (Sutcliffe, 1980).

This is a report of an attempt to generate a Word Fluency test with these properties for repeated measurement of divers. The development of parallel Word Fluency tests suitable for repeated measures will be described in detail. This development is a new venture that refutes test experts' claims that "completely parallel components are not attainable unless one takes only a very small number of measures" (Lord & Novick, 1968, p. 139) or "....it is seldom true in practice that any great number of repeated measures approximate parallel measurements" (p. 134). Recently the extensive development of repeated measurements of human performance have been attempted and documented (e.g. Harbeson, Bitter, Kennedy, Carter, and Krause, 1983).

EXPERIMENT 1

Method

A tentative set of candidate letters was chosen. The letters were then used in Word Fluency testing of divers. The results were examined with special emphasis on the following questions: Were the letters equivalent in terms of the number of words evoked, and the variability of the number of words? Were there differences among the divers in the ability reflected by this test? Do the individual differences hold up over time? Are the scores obtained on different occasions of testing altered by previous testing with other letters?

Choice of Letters

A simple approach was taken in choosing candidate letters. It was reasoned that, in general, divers would think of more words starting with a particular letter if more words actually started with that letter. Several dictionaries were consulted, and the 26 letters were ranked according to the relative frequency of words associated with that letter. Judgment was used in limiting the representation of letters beginning common prefixes like "un" or

"non". Seven letters were selected that were neither among the more nor less common first letters of words. The letters R, F, H, E, I, L, and G were all associated with about the same number of words. They were the letters first tested for use in repeated measurements of Word Fluency.

Subjects

Enlisted U.S. Navy saturation divers were the subjects. Independent, identical experiments were conducted at the Naval Medical Research Institute in Bethesda, MD and at the Navy Experimental Diving Unit in Panama City, FL. Fourteen subjects representative of a wide range of ages, and Naval ratings, consented to participate.

Research Design

The same design was used simultaneously at each facility. Seven divers, seven letters, and seven occasions of measurement were arranged in a Latin Square design. This design provided for each diver to be tested once with each letter, and each letter was used only once as the first, or second, etc. letter tested at each location.

Procedure

Each diver was tested with all seven letters in one session. Divers were told the purpose of the study and how the results would be used. Test times were arranged for the convenience of each diver. The diver was instructed to name all the words he could think of that started with a given letter. A test duration of one minute was allowed for each letter, based on preliminary experience with this subject population. Additional time did not yield results which were useful. One practice trial was conducted using the letter B to ensure that the diver understood what he was to do. The test letters were then presented in a different random order to each subject, within the constraints of the Latin Square.

Results

The results were remarkably similar at each of the two testing facilities. Of the three experimental factors (subjects, practice, and letters), subjects accounted for the largest part (about 45%) of the variability of the results. The differences among subjects were statistically significant at each location [$F(6,30) = 9.12$ and 4.68, $p < .01$]. The variability among subjects did not change appreciably from one letter to another (see Table 1). Furthermore, subjects tended to retain their rank order of Word Fluency irrespective of the test letter used. The average correlation between scores obtained with different letters (except I) was .60. The letter "I" was somehow unlike the others, having an average correlation with the other six letters of only .28. A statistical test (Steiger, 1980) indicated stability of individual differences [$X^2(20) = 15.08$, $p = .77$]. That is, the most fluent divers remained more fluent, and the least fluent remained less fluent over several trials of testing.

TABLE 1: Number of words produced in a word fluency test with 14 divers in Experiment 1.

Letter:	E	F	G	H	I	L	R
Average:	11.9	14.5	14.1	13.4	9.1	13.8	13.6
Variance:	16.1	27.1	9.9	23.0	9.0	20 6	14.7

NOTE: Honestly Significant Difference of a pairwise comparison of averages ($p < .05$ for all comparisons) is 3.7. Cochran's test indicates that the variances are homogeneous ($C = .22$, $p > .05$). See Kirk (1968) for descriptions of these statistics.

The high reliability of responses to single letters (E, F, G, H, L, or R) could be improved even further by constructing a test score that is the accumulated number of words elicited by two or more letters. According to the Spearman-Brown formula (Winer, 1971) the estimated reliability of a two or three-letter Word Fluency test would be .75 or .82, respectively.

Practice had little, if any, effect on test scores at either location. Seven trials of practice accounted for almost none of the variability of test scores [about 5%; $F(6, 30) = 1.05$, $p > .25$ and .506, $p > .5$].

The primary focus of this experiment was to establish a set of letters that would be equivalent for purposes of repeated testing of divers' Word Fluency. The effect of letters accounted for 15 to 20% of the variability of test scores at either of the two facilities. Differences among the seven candidate letters were statistically significant at one location [$F(6, 30) = 3.80$, $p < .01$], and marginal at the other [$F(6, 30) = 1.78$, $p < .25$]. At both locations the letter "I" evoked fewer words than the other letters. Table 1 shows the number of words elicited by each letter, averaged across both locations. For purposes of pairwise comparisons among the letters, Tukey's Honestly Significant Difference ($p < .05$) was calculated (Kirk, 1968). The Honestly Significant Difference is 3.7 words. Letter I appears to be the sole contributor to the differences among the letters.

Discussion

The presence of stable individual differences among divers on the Word Fluency test encouraged further research into the use of this test as a part of a neuropsychological battery to be employed in long, deep saturation dives. The absence of any large or irregular practice effect will make interpretation of repeated test scores easier. A set of letters: F, G, H, L, E, and R were recommended as equivalent for purposes of repeated testing of divers' Word Fluency.

EXPERIMENT 2

The results of Experiment 1 were encouraging. However, it seemed that more than six letters might be needed if multi-letter tests were to be administered on several occasions. Could other letters be used? Further, is there any merit to the assumption that divers would think of more words starting with a particular letter if more words actually started with that letter? In Experiment 2 we examined these questions.

Method

Eight U.S. Navy saturation divers participated as part of the training for a saturation dive. Fifteen randomly chosen letters were employed in a Word Fluency test procedure identical with that described for Experiment 1. The letters, in the order in which they were presented to the divers, were G, H, E, P, O, Y, I, T, V, J, K, M, B, A, and D. Three letters were presented per day, across five days.

TABLE 2: Number of words produced in a word fluency test with eight divers (Experiment 2).

Day	Letter	Page Count	Average	Variance
1	G	35.6	10.8	6.8
	H	43.8	14.3	3.9
	E	39.6	10.1	17.8
2	P	88.1	16.5	14.5
	O	30.6	10.0	5.4
	Y	3.9	6.8	3.1
3	I	45.6	10.5	8.9
	T	60.2	16.1	18.1
	V	18.4	8.6	6.9
4	J	9.5	8.5	10.6
	K	9.9	4.3	3.4
	M	57.6	11.0	7.1
5	B	59.2	13.3	5.1
	A	65.0	8.8	12.8
	D	55.2	14.6	30.0

NOTE: Honestly Significant Difference (Kirk, 1968) between averages is 4.9. The Honestly Significant Differences is based on $p < .05$ for all comparisons.

Results

Table 2 shows the mean number of words evoked by each letter. Also shown are dictionary page counts for each letter. It is clear from these data that the number of words evoked by a letter is highly correlated (r = .79) with the number of words actually starting with that letter. In addition, the variability of the number of responses increased as the average number of responses increased. Finally, the reliability of the daily 3-letter tests was r = .79, which is very similar to what was predicted (r = .82) on the basis of Experiment 1.

Discussion

This experiment verified the assumption made in Experiment 1, namely that divers would think of more words starting with a particular letter if more words actually started with that letter. In an experiment employing many letters, the number of words starting with each letter would have to be taken into account. For example, analysis of covariance (Kirk, 1968; Winer, 1971) could be used to make comparisons among results obtained with large sets of letters, taking into account their varying dictionary word counts.

The relation between the average number of responses and the variability of the number of responses, shown in Table 2, suggests that Word Fluency data obtained with large sets of letters may need a logarithmic or other transformation in order to conform to the assumptions of traditional analyses (Kirk, 1968).

EXPERIMENT 3

Experiment 1 had shown that individual differences of Word Fluency are stable across letters over a period of minutes. Experiment 2 indicated that Word Fluency can be measured reliably over several days. However, most applications of Word Fluency testing to saturation diving would involve periods of weeks or months between occasions of testing. Experiment 3 was intended to examine long-term stability of differences among divers on Word Fluency.

Method

Seven divers from Experiment 1 were retested using the letters R, H, L, D, M, F, and G. These letters were chosen to be similar in evocativeness to those used in Experiment 1. The procedure was identical to that used in Experiment 1, including refresher practice with the letter B. Experiment 3 was performed six months after Experiment 1.

Results

The average number of words produced per letter increased significantly from Experiment 1 to Experiment 3. The difference was four words per letter [$t(30 = 5.77, p < .005$]. This difference was probably due to the practice during Experiment 1 benefiting performance in Experiment 3. However, the inter-subject variability of the number of words produced was unchanged [MS for subjects was 52.27 in Experiment 1, and 52.74 in Experiment 3, $F(6, 6) = 1.01, p = .5$]. There were three variables in the Latin Square design of Experiment 3: letters, occasions of measurement (practice), and subjects. Neither the occasion of measurement nor the particular letter used affected the number of words elicited [$F(6, 30) = .69$ and .68, respectively, $p > .05$]. In contrast, differences among subjects were salient [$F(6, 30) = 4.05, p < .01$]. In these respects, the results of Experiment 3 were very similar to results of Experiment 1.

In order to examine the long-term stability of divers' Word Fluency, we used Steiger's (1980) statistic to test the hypothesis that reliabilities over a six-month period were no different than reliabilities within Experiments 1 or 3. The ninety-one correlations based on the data from Experiments 1 and 3 were compatible with the hypothesis that individual differences were stable over six months [$X^2(90) = 82.77, p = .69$]. Hence, the most fluent divers tended to remain most fluent, and the least fluent remained lost for words.

EXPERIMENT 4

The Word Fluency test was then used to test divers before, during, and after a helium-oxygen saturation dive to a simulated depth of 259m underwater. The duration of the dive was thirty days.

Method

Subjects

Seven male U.S. Navy saturation divers served as volunteer test subjects. They ranged in age from 29 to 34 years. All men were in good health with no prominent speech defects. Five of the seven subjects were experienced in word fluency testing.

One female and six male U.S. Navy personnel served as volunteer controls for the test subjects. Their ages ranged from 26 to 43 years. None of the control subjects were experienced in word fluency testing. All controls were in good health and free from obvious speech defects.

Materials

Nine letters were selected for testing: R, H, B, D, M, P, F, G, and L. The selection of letters was based upon previous testing. A stop watch was used to time the test periods.

Procedure

All subjects were briefed on the purposes and goals of the testing. Each subject was tested once before the dive, once during the dive when the compression facility was at 259m, and once after the dive. Pre and post-dive testing was conducted in a quiet room with the examiner and subject facing each other. At 259m, each diver was isolated in one chamber of the hyperbaric complex and interacted with the experimenter over a headset on a clear communication system. All subjects were tested within 36 hours of each other on each occasion. Three different letters were used on each occasion of measurement, with all subjects receiving the same letters on any particular occasion (i.e. before dive: R, H, B; during dive: D, M, P; after dive: F, G, L). Each test period included 20 seconds of practice in which the subject was instructed to name as many words as he could in 20 seconds starting with the letter "S". Specific instructions were as follows:

"This is a test of word fluency. I will tell you a letter of the alphabet. Your task is to name out loud as many words as you can in one minute starting with this letter.

* You may use derivatives of words; for example, "boy-boyish-boycott"; however, plural forms of words will not count.

* Try not to use proper names; that is, "Mary, Margaret, Michael" or "Maine, Michigan, Maryland".

* Sometimes you may have difficulty in thinking of new words; do not give up! Some people find it helpful to return to a word previously stated, and again start to free associate. Others find it helpful to picture the words in their minds.

* Do you have any questions?

* We will start with practice letter for 20 seconds.

* Name as many words as you can in 20 seconds starting with the letter "S".

* BEGIN"

Feedback on performance was provided to the subjects after they completed all testing on each occasion of measurement. The subjects did not know in advance of the test which letters would be used.

Results

Compared to the control group, the dive groups suffered an impairment of Word Fluency indicated by a weaker trend of score improvement during the dive [$F(2, 24) = 3.57$, $p < .05$]. The divers did not exhibit the robust learning curve over the three occasions of measurement (pre-dive, 259m, post-dive) that the controls exhibited. The contrast between results from the two groups is depicted in Figure 1.

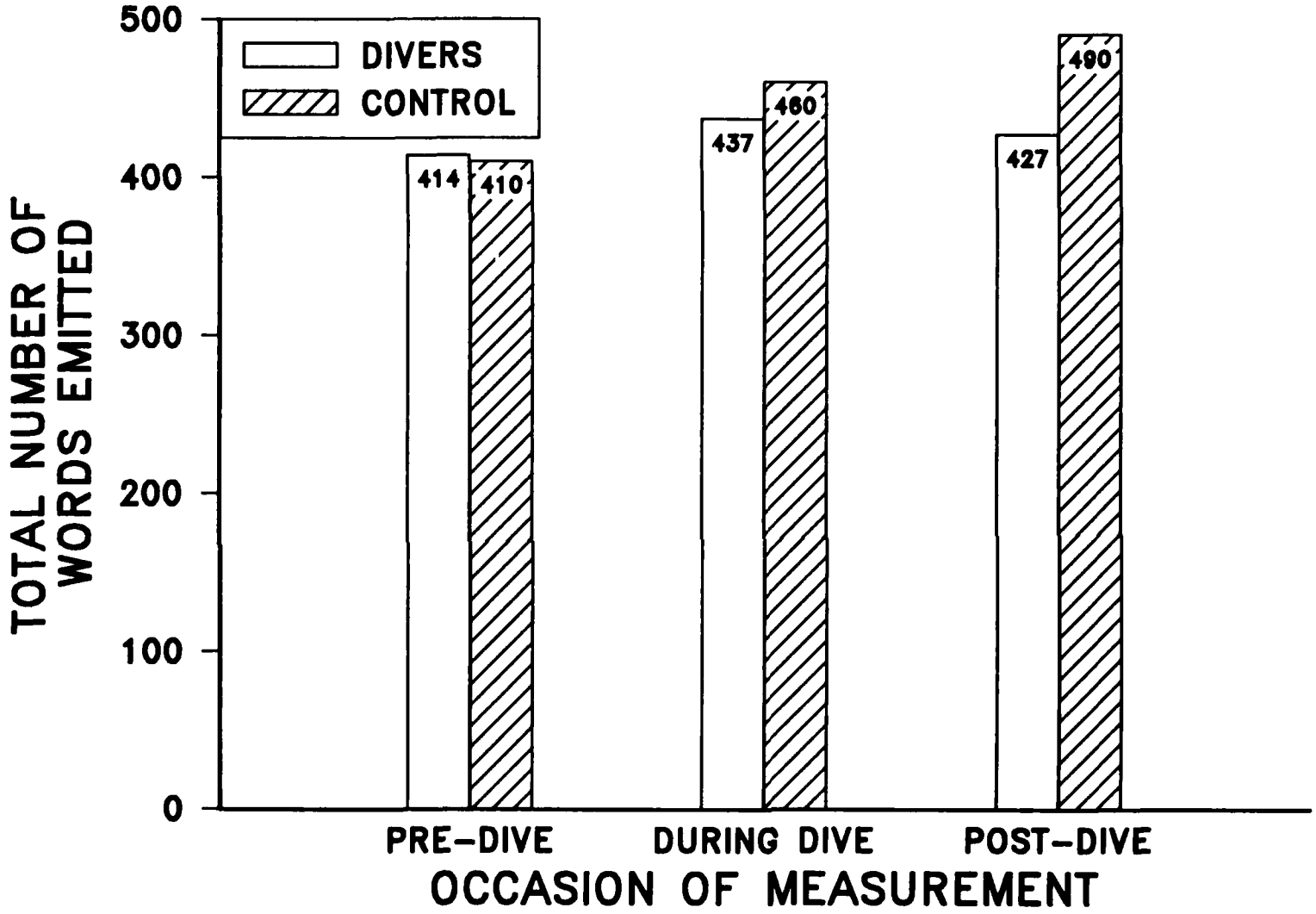

FIGURE 1: The number of words emitted by a diver and (surface) control groups before, during, and after a 259m, 30-day saturation dive.

The difference between the dive and the control group's performance at 259m was not statistically significant. The between-group error term [MS (12) = 372.03] for that contrast provided a crude statistical test compared to the within-groups error term [MS (24) = 23.42] that was employed to show the relative impairment of the dive group's learning curve.

Other neuropsychological tests were administered in addition to the Word Fluency test. Trail Making and Symbol Digit Modalities revealed slightly poorer performance from five of the seven divers at 259m when compared to scores obtained before and after the dive. No significant change was found between pre and post-dive performance auditory evoked potentials, stabilometer, or the Minnesota Multiphasic Personality Inventory.

This experiment demonstrated the usefulness of repeated Word Fluency testing. Repeated measurements provided a sensitive statistical test for within-subjects effects and interactions. The between-subjects error term is hopelessly large. It would be the experimenter's only recourse for statistical tests without repeated measurement. In addition, performance on the Word Fluency test appears to be affected by the stress associated with a deep, long, undersea dive. This finding encourages the use of the Word Fluency test along with other tests in the neuropsychological assessment of divers.

EXPERIMENT 5

In the previous experiment the usefulness of repeated Word Fluency testing was demonstrated during a saturation dive. However, the divers and the control group in Experiment 4 were not matched on several factors which could contribute significantly to variability in performance between the groups. To minimize these sources of variability, a systematic replication of Experiment 4 was undertaken during a helium-oxygen dive to a simulated depth of 335m. The duration of the dive was 30 days.

Method

Subjects

Twelve male U.S. Navy personnel served as volunteer subjects. Eleven men were U.S. Navy saturation divers, and one man was in preparation for diver training. All subjects were in excellent health with no obvious speech impediments. Six subjects were selected to participate in the saturation dive, and the remaining six personnel were matched to the dive group on the variables of age, sex, years of education, and experience with the Word Fluency test. Table 3 presents these relevant variables by groups.

Materials

The nine letters used in Experiment 4 were used again in this replication: R, H, B, D, M, P, F, G, and L.

TABLE 3: Relevant characteristics on which the diver and control groups were matched in Experiment 5. WF = word fluency test.

	No. Previous WF tests	AGE (Yrs)	EDUCATION (Yrs)
Diver 1	6	32	12
Control 1	4	33	12
Diver 2	3	28	13
Control 2	3	28	12
Diver 3	3	25	12
Control 3	3	25	12
Diver 4	0	26	12
Control 4	0	26	12
Diver 5	0	34	12
Control 5	0	34	12
Diver 6	0	28	12
Control 6	0	28	12

Procedure

The procedures were identical to those used in Experiment 4, with the divers now tested when the hyperbaric complex was at 335m.

Results

The number of words emitted by the control and diver groups were essentially identical both before and during the dive (Figure 2). Word Fluency testing while the hyperbaric complex was at 335m did not reveal a reduction in fluency as a function of hyperbaria. A two-factor mixed design analysis of variance (Myers, 1972) failed to detect any significant differences in word fluency as a function of group (diver vs. control), trial (pre, during and post-dive), or group by trial interaction. Post-dive the average number of words emitted by the divers ($\bar{X}$ = 20.5) was greater than that of the control group ($\bar{X}$ = 18.4), but not significantly so [$t(10) = 1.95$, $p > .05$]. The additional neuropsychological testing surrounding this saturation dive revealed no lasting cognitive or psychomotor impairment.

A comparison of the word fluency of divers and controls from Experiments 4 and 5 is presented in Table 4. Within each experiment the average number of words emitted per letter by control and dive groups was remarkably similar. The only substantial difference in fluency between a dive group and its control was found in Experiment 4 with the letter F. Examination of the individual data revealed that one control emitted an extremely high number of words (35) which inflated the mean for his group.

Examination of the data from Experiments 1-3 and 4-5 indicates that a greater number of words are emitted per letter in the later experiments. This can be attributed to a small but significant change in the instructions to the subjects and scoring by the examiner. The standardized instruction in Experiments 4-5 allowed for the counting of derivatives of words, whereas during the earlier studies this was not allowed. It is unlikely that the population of divers has become substantially more fluent during the time period covered by these studies.

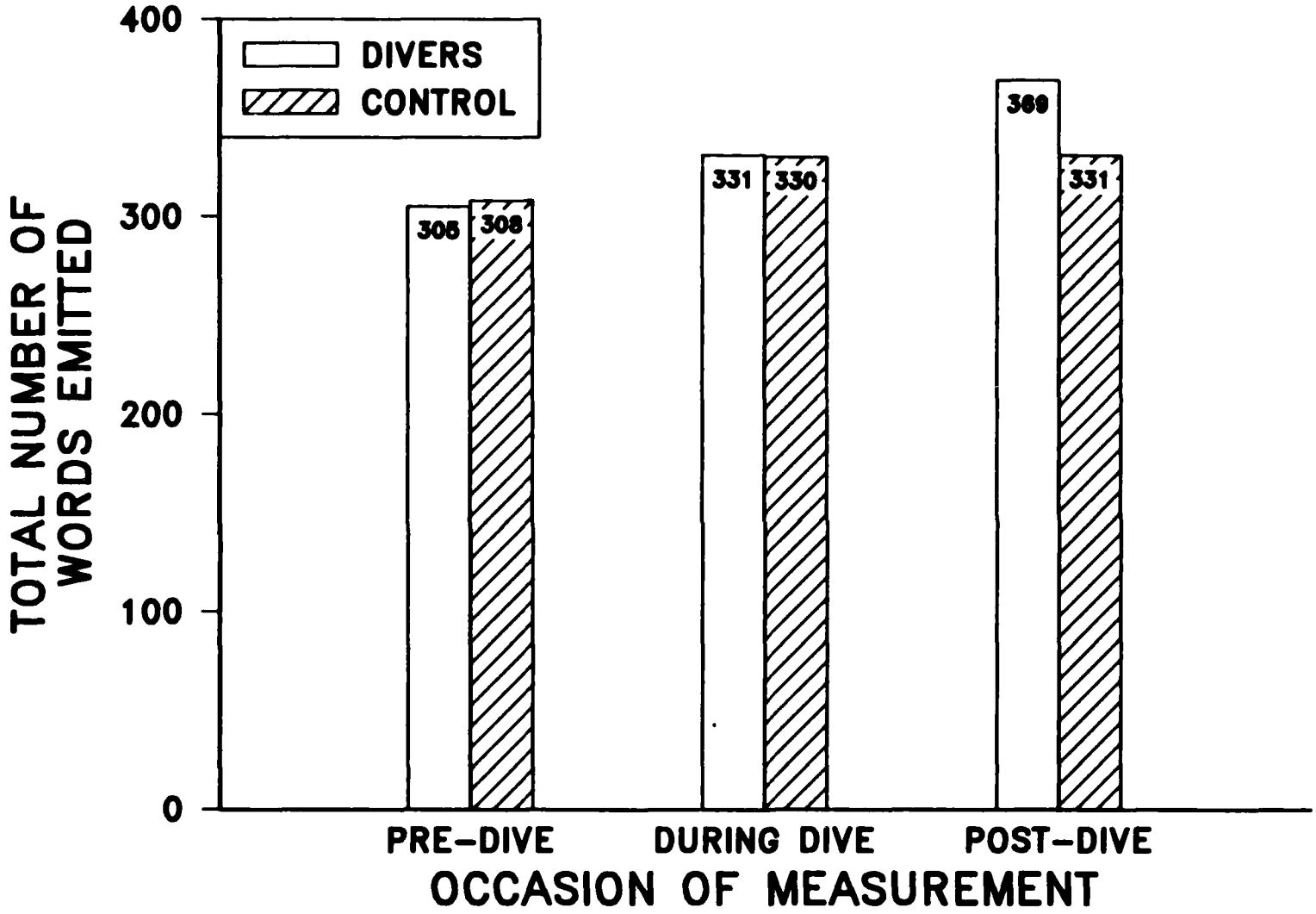

FIGURE 2: The number of words emitted by a diver and (surface) control groups before, during, and after a 335m, 30-day saturation dive.

TABLE 4. The mean number of words emitted in Experiments 4 and 5 as a function of group, occasion of testing, and letter.

			LETTERS								
			Pre-dive			During dive			Post-dive		
Experiment	Group	n	R	H	B	D	M	P	F	G	L
4	Diver	7	19.0	19.7	20.4	22.3	20.4	19.7	18.9	21.4	20.6
	Control	7	18.8	18.6	20.6	21.9	20.6	23.1	25.9	22.3	22.1
5	Diver	6	16.7	16.3	17.8	20.3	17.7	17.1	22.7	17.8	21.0
	Control	6	17.0	17.2	17.2	20.0	16.7	18.3	19.8	16.3	19.0

CASE STUDY

Word Fluency and Decompression Sickness of the Central Nervous System

A diver experienced symptoms of severe decompression sickness after a 50-minute helium-oxygen bounce dive to pressure equivalent to 24 meters under sea water. The symptoms included mental confusion, slurred speech, and memory deficits. After medical examination, the diver was treated by recompression in a hyperbaric chamber using a standard Navy saturation treatment schedule. Alleviation of symptoms was reported during this treatment. Five days after completion of the recompression treatment, the diver reported that he felt continually tired and that his wife had noted that he had memory lapses since the injury. His enunciation continued to be impaired slightly. This was medically diagnosed as possible residual neurological deficits from the decompression sickness. Before commencing additional recompression therapy, several neuropsychological tests were administered to establish the diver's present level of performance. Word Fluency testing, using methods previously described, was included. The diver's mean Word Fluency score was 14.1 for seven letters (R, H, L, D, M, F, G) before the recompression treatment. Four of seven letters elicited a substandard response (10-12 words per letter).

Immediately after completing the second recompression treatment the diver reported he felt much better and his overall mean Word Fluency score was 20.6, with a range of 19-24. After another treatment the following day, the diver's mean Word Fluency score was 20.4 with a range of 16-24. A medical examination after the third recompression treatment indicated complete resolution of the mild central nervous system residuals of decompression sickness. At this time all neuropsychological test scores were also within normal limits. This example illustrates the clinical (non-experimental) usefulness of repeated Word Fluency testing.

CONCLUSIONS

The series of experiments described in this report provides a basis for endorsement of a Word Fluency Test for repeated measurement. The subjects were U.S. Navy saturation divers, so that there would be clear applicability of the results to that group.

It was shown that Word Fluency scores can be obtained which have desirable properties of means (averages), variances, and correlations between measurements. Scores composed of the total number of words elicited by three letters (three minutes) had acceptable reliability. Intervals of minutes, days, or several months between measurements were considered and recommendations were made regarding repeated measurement of Word Fluency.

One of the most remarkable findings of this research was the strong relation between the number of words evoked by a letter in a Word Fluency testing, and the number of words actually beginning with that letter. This seems to imply that a subject's memory access to words beginning with any particular letter is constrained by the actual number of words beginning with that letter.

Word Fluency was shown to be affected by a long, deep saturation dive. In this instance the effect (a difference in trend for control and dive groups) was made apparent only by measuring repeatedly. Furthermore, repeated measurement provided adequate statistical power with a small sample. Even though no statistically significant results are found in a particular experiment or case, analysis-of-variance mean squares can be accumulated over several instances to obtain statistical power to detect subtle effects. Subtle impairment of Word Fluency can represent mild linguistic deficits in expressive speech which have wide ramifications as shown in the case of the diver with CNS decompression sickness. The methods demonstrated in this report can be used for sensitive repeated measurements of Word Fluency.

References

1. Anger, K., Personal Communication, 1984.

2. Borkowski, J.G., Benton, A.L., and Spreen, O. (1967) Word Fluency and brain damage. Neuropsychologia, 5, 135-140.

3. Carter, R.C. and Biersner, R.J. (1972) U.S. Navy enlisted jobs: An analysis. Report No. NBDL-82R010, Naval Biodynamics Laboratory, New Orleans, LA. (NTIS No. ADA 121760).

4. Ekstrom, R.B., French, J.W., and Harman, H.H. (1979) Cognitive Factors: Their identification and replication, Multivariate Behavioral Research Monograph 79-2.

5. Ekstrom, R.B., French, J.W., Harman, H.H., and Derman, D. (1976) Manual for kit of factor-reference cognitive tests. Princeton, N.J.: Educational Testing Service.

6. Filskov, S.B. and Boll, T.J. (Eds.) (1981) Handbook of clinical neuropsychology. New York: Wiley.

7. Harbeson, M.M., Bittner, A.C., Jr., Kennedy, R.S., Carter, R.C., and Krause, M. (1983). Performance evaluation tests for environmental research (Peter): Bibliography. Perceptual and Motor Skills, 57, 283-293.

8. Kirk, R.E. (1968) Experimental design: Procedures for the behavioral sciences. Belmont, CA: Brooks/Cole.

9. Lewis, V.M. & Baddeley, A.D. (1981) Cognitive performance, sleep quality, and mood during deep oxyhelium diving. Ergonomics, 24, 773-793.

10. Lezak, M. Neuropsychological assessment. (2nd Ed.). (1983) New York: Oxford University Press.

11. Lord, F.M. and Novick, M.R. (1972) Statistical theories of mental test scores. Reading, Massachusetts: Addison-Wesley Publishing Co.

12. Myers, J.L. (1972) Fundamentals of Experimental Design. Boston, MA; Allyn and Bacon, Inc.

13 Steiger, J.H. (1980) Tests for comparing elements of a correlation matrix. Psychological Bulletin, 87, 245-251.

14. Sutcliffe, J.P. (1980) On the relationship of reliability to statistical power. Psychological Bulletin, 88, 509-515.

15. Taylor, C.W., Ghiselin, B., and Yagi, K. (1967) Exploratory research on communication abilities and creative abilities. Salt Lake City, Utah: University of Utah.

16. Thurstone, L.L. (1938) Primary mental abilities. Chicago: University of Chicago Press.

17. Winer, B.J. (1971) Statistical principles in experimental design. (2nd Ed.). New York: McGraw-Hill.

NORMATIVE DATA

The following table presents a listing of letters and the average number of words evoked by each letter. All data were obtained through formal word fluency testing with U.S. Navy officer and enlisted divers at the Navy Experimental Diving Unit and the Naval Medical Research Institute. The mean for each letter represents data obtained from different divers on each occasion; i.e. a diver contributed only once to each letter's mean score.

LETTER

	B	D	E	F	G	H	I	L	M	P	R
$\bar{X}$	17.6	19.1	9.9	19.8	17.9	16.0	8.3	17.8	17.8	20.2	15.9
SD	5.1	5.0	3.1	6.3	4.6	5.0	3.2	5.4	5.1	4.3	5.1
N	83	32	7	40	40	102	7	45	32	20	102

Examination of the data in the table suggests that the letters are all relatively homogeneous in their evocative properties except for the letters E and I. If one desires to further limit the test letter variability, one could use as a set of letters B, D, F, G, L and M (range 17.6 - 19.8). Standard deviations are also similar for all letters save E and I.

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