U.S. NAVAL
MEDICAL RESEARCH LABORATORY

Submarine Base, New London, Conn.

Vol. XXIII, No. 23 REPORT NO. 441 10 November 1964

PSYCHOLOGICAL AND PSYCHOPHYSIOLOGICAL EFFECTS OF CONFINEMENT IN A HIGH-PRESSURE HELIUM-OXYGEN-NITROGEN ATMOSPHERE FOR 284 HOURS

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Benjamin B. Weybrew,
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Bureau of Medicine and Surgery, Navy Department
Research Project MR005.14-2100-3.10

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Approved by:

Walter R. Miles, Ph.D.
Scientific Director

Approved by:

E. H. Ninow, CDR MC U.S.N.
Dir., Med. Research Dept.

Released by:

C. L. Waite

CAPT MC, U.S.N.
Commanding Officer
U.S. Naval Submarine Medical Center

SUMMARY PAGE

THE PROBLEM

To ascertain whether peripheral indices of autonomic nervous system function would show differential change patterns in three men who were confined for approximately twelve days in an atmosphere of helium, oxygen, and nitrogen at a pressure equal to seven atmospheres (as would be experienced at a depth of 200 feet in the sea).

FINDINGS

The three men showed different patterns of autonomic reactivity and recoverability as the experiment progressed. These differences may be related to the potentiality of men to adjust to confinement in a hyperbaric, gaseous environment of the composition used in this experiment.

APPLICATIONS

Capacity to adjust to prolonged confinement to a deep sea environment as in underwater laboratory stations may be related to emotional responsivity to the total situation. Suggestions as to the kind of person who adjusts optimally to these conditions are provided.

ADMINISTRATIVE INFORMATION

This investigation was conducted as a part of Bureau of Medicine and Surgery Research Project MR005.14-2100 - Psychological Evaluation of Personnel for Submarine Duty, under Subtask (3), Stress and Fatigue Research. The present report is No. 10 on this Subtask and was approved for publication on 10 November 1964.

Published by the U. S. Naval Submarine Medical Center, Groton, Conn.

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ABSTRACT

Three submariners were confined in a chamber for 284 hours in a helium-oxygen-nitrogen environment at 7 atmospheres pressure. Electrodermal conductance (EDC) levels, changes and recoverability prior to and following hyperventilation and breathholding were obtained before, three times during, and once at the termination of the pressurization phase of the experiment. In addition, breathholding time, time-span estimation and indices of spatial perception were obtained during the same measurement sessions. The results suggested individual differences in general excitability (EDC level), in autonomic reactivity (change in EDC during hyperventilation), in recoverability (rate of EDC recovery during breathholding), in breathholding time and in time estimation. Some of these change patterns, particularly in autonomic indices, may be useful predictors of individual differences in capacities to adjust to confinement in an exotic gaseous atmosphere at high pressure. The subject sample was too sparse (N=3) to suggest definite group autonomic or other effects of these conditions.

PSYCHOLOGICAL AND PSYCHOPHYSIOLOGICAL EFFECTS OF CONFINEMENT IN A HIGH PRESSURE HELIUM-OXYGEN NITROGEN ATMOSPHERE FOR 284 HOURS[1]

The literature of submarine and diving medicine contains a number of studies designed to investigate the physiological effects of exposure to various gaseous mixtures at varying ambient pressures (Hoff & Greenbaum, 1954; Schaefer, 1959). By and large these studies have emphasized those physiological processes which in one way or another are involved with decompression sickness of obvious significance for submarines and diving medicine. In contrast, there have been relatively few studies designed to ascertain what if any psychophysiological and behavioral effects result from exposures to these conditions. The present investigation, in terms of scope, is exploratory and represents an attempt to identify gross changes in autonomic nervous system (ANS) function, and to a lesser extent, changes in perceptual, motivational and cognitive processes.

The data discussed in the present paper were collected as part of the fifth study of the so-called Genesis series (Genesis E), all designed to determine the effects of prolonged exposure to a helium, oxygen, nitrogen environment. The first two studies (Workman, Bond, & Mazzone, 1962) utilizing rats, goats, and monkeys as subjects showed no significant differences in the histological, blood, and pulmonary variables measured. Certain of the pulmonary data from the present study of the series have already been published (Lord, Bond & Schaefer, 1964).

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[1] The opinions or assertions contained herein are the private ones of the writer and are not to be construed as official or reflecting the views of the Navy Department or the Naval service at large.

METHOD

SUBJECTS

The subjects were two senior Chief Petty Officers and one Submarine Medical Officer, all of whom had had considerable training in diving techniques. The two Chief Petty Officers had been instructors in the Escape Training Tank and as a result were thoroughly familiar with the technology of underwater survival, decompression problems and the like. The Submarine Medical Officer having had advanced training in diving physiology not only served as a subject for the experiment but also as a physician capable of providing immediate medical treatment, should a casualty occur.

PROCEDURE

The three subjects were confined for 284 hours to a chamber the volume of which was 30 cubic meters. The gaseous composition of the atmosphere in terms of partial pressures (millimeters of mercury) was maintained as nearly as possible as follows: Helium, 4,680 m.m.; oxygen, 205 m.m.; nitrogen, 302 m.m. and carbon dioxide, 8.8 m.m. Although an attempt was made to maintain the chamber at 88.8 PSI relative pressure, slight fluctuations occurred as the experiment progressed. Food, test materials, mail, and the like were delivered to the subjects by means of a small interconnecting, pressurizable compartment. Depending upon the inside and outside relative illumination level, the subjects could see outside through a six-inch, "one-way" mirror glass port. TV viewing was allowed through this port on a demand basis, the subject's demand varying from four to seven hours of the daily waking period.

Palmar skin resistance was utilized as an index of individual differences in Autonomic Nervous System function, particularly that of the Sympathetic System. The procedure utilized to obtain the skin resistance measures was as follows: First, each subject was instructed in the technique of placement of the 1-inch cup zinc electrode in the palm of the hand and the steel plate reference electrode on the forearm. Commercial EKG electrode paste was used. Prior to each of the five measurement sessions, each subject was allowed ten minutes to adapt to the electrodes and thus insure their proper placement. Skin resistance levels and changes were measured by means of a Fels Dermohmeter which impressed a constant current of 70 microamperes.

A five-minute basal measurement period followed the ten-minute adaptation period. Resistance level was recorded continuously by polygraph during this basal period, the subject being instructed to lie as still as possible in the supine position maintained during the electrode adaptation period.

The subject then was instructed to hyperventilate deeply three times and to hold the fourth inspiration as long as possible. Five scores or indices were obtained from this experiment during each measurement session.

1. Basal Conductance Level (BL) was computed as the mean of the resistance levels obtained every thirty seconds of the five-minute basal period. Units were micromhos conductance.

2. The Displacement Index (DI) was the difference between the maximum drop in resistance during hyperventilation and the basal level converted to per cent of the latter.

3. Breathholding Recovery Slope (BH-RS) was computed as the rate of resistance recovery during breathholding (actually the slope of the recovery curve), the units being ohms recovered per second.

4. Recovery Index (RI) was computed from the difference in the conductance level during the ten-minute recovery period following breathholding and the basal level changed again to per cent of basal conductance level. The recovery level itself was calculated as the mean of the conductance levels obtained every thirty seconds during the ten-minute recovery period.

5. Recovery Quotient (RQ) the ratio of RI to DI. Since both RI and DI are percentages with BL as the denominator, BL cancels leaving RQ the simple ratio of recovery to displacement.

6. Breathholding Time was measured by means of a stopwatch and corroborated by the changes in skin resistance level coincident with the onset and termination of breathholding and recorded on the polygraph.

Ability to integrate geometrical forms perceptually was measured by means of the revised Minnesota Paper Form Board Test[2], (See Appendix A for examples of test items). Two parallel forms of this test were administered to each subject once at the beginning of the experiment and once after six day's confinement.

Estimates of the perceived passage of time were obtained once at maximum pressure, again early in the decompression period, and just before the termination of the experiment. These estimates were obtained by asking the subjects with eyes closed to estimate a 90-second interval. Accuracy of time perception was calculated as percentage error, plus or minus.[3]

With only three subjects involved, statistical techniques were largely precluded. However, a gross check of the significance of changes between measurement sessions was provided by a non-parametric technique developed by Friedman (1937) and presented in simplified terms by Wilcoxin (1949). This statistical technique was utilized for all of the measures obtained from this experiment.

The rationale for the particular kind of measures obtained as part of the experiment may not be immediately evident. The utilization of palmar conductance levels, changes, and recoverability during and following the hyperventilation-breathholding procedure has been found to provide indices, presumably of sympathetic nervous system (SNS) function, which correlate with personality traits assessed by means of observer ratings (Weybrew, 1959 & Weybrew, 1964). It is assumed that exposure to close physical as well as psychological space and to the uncertainties of breathing a foreign atmosphere at unusually high pressure would be stressful and therefore would result in emotional changes for which peripheral indices of autonomic function would be a valid index.

As a result of the greatly-reduced viewing distances possible in the chamber, it was thought that there might be changes in form perception, particularly when the measurement procedure neces-

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[2] Test prepared by R. Likert and W. H. Quasha, published by the Psychological Corporation, New York.

[3] Individual Rorschach and Sentence Completion tests were administered prior to, and once during the experimental periods. These results will be summarized in another paper by CDR H. B. Molish, MSC, USN who was responsible for the administration of these tests.

sitated the subjects integrating form percepts into a total gestalt. The Minnesota Paper Form Board Test was utilized to examine possible changes in these perceptual processes.

RESULTS

CHANGES IN AUTONOMIC FUNCTION AS INDICATED BY PALMAR CONDUCTANCE SCORES

Each subject was measured five times during the experiment, once prior to their admission to the chamber and four times during the experimental period itself. Information concerning the conditions existing during these measurement sessions is contained in Table I.

The literature appears rather convincing that Electrodermal Response (EDR) as well as Electrodermal Conductance (EDC) are sensitive indicators of level of tension or "activation level" (Woodworth & Schlosberg, 1954). Since EDR and EDC reflect activity of the branch of the SNS innervating certain of the sweat glands, it was assumed that these measures would to a degree at least indicate the general excitation level of the subjects involved in this experiment.

Figure 1 shows the Basal Conductance Level (units are micromhos) of the three subjects for the five experimental sessions. Assuming that high conductance level is positively correlated with general excitation level, the data in Figure 1 indicate that two subjects Ba and Ma showed similar conductance patterns throughout the experiment. On the other hand, the physician subject (Bu) showed heightened tension level prior to entrance into the chamber with gradual reduction in level during the period of maximum pressure. Excitation level rose for this subject during the two measurement sessions during decompression, reverting to the pre-experimental control level as the termination of the experiment neared. The two Chief Petty Officers on the other hand showed increased tension level midway in the experiment but decreases at the beginning and end.

Certain of the results of a somewhat similar study involving the confinement of six men in an altitude chamber maintained at a simulated altitude of 1,000 feet (55% oxygen) for seven days might be mentioned (Hanna, 1962). Heart rate, respiration rate and skin temperature

Table I
Atmospheric Conditions during the
Five Measurement Sessions

Measurement Session	Bottom Time	Pressure[a]	Oxygen[b]
Pre-Experimental	(Outside Chamber)	Standard	21%
I	213 hours	88.8 PSI	3-5%
II	244 hours	88.8 PSI	3-5%
III	268 hours	62 PSI	7-10%
IV	284 hours	1.3 PSI	21-24%

[a] Relative pressure in pounds/sq.in.

[b] Approximate volumes percent oxygen in breathing air.

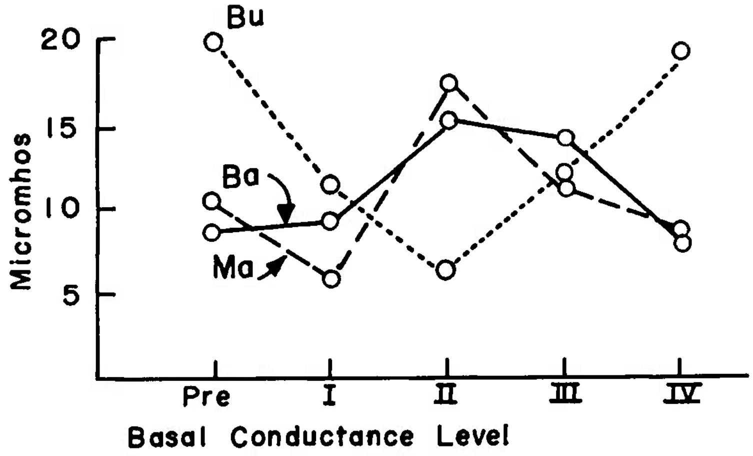

Figure 1. - Basal Conductance Level

were measured every 24 seconds. On the other hand, continuous plantar conductance measures were made both during task performance and rest periods. Plots of mean conductance levels over the seven days showed, in general, the pattern depicted by a similar plot (Figure 1) for only one of the three subjects in the present study, namely, the physician (Bu). The author suggested as we do in the present study (in the case of the one subject, Bu at least) that at the beginning confinement results in hyperexcitability, moderating after 2-3 days, followed as the experiment nears completion, by a reversion to the previous elevated excitability level. Although antithetical in terms of pressurization, the two experiments would seem to be comparable at least in terms of the confinement aspect.

There is some evidence that the reactivity of the sympathetic Nervous System may be inferred from relative changes in EDC during hyperventilation (Weybrew, 1959). Figure 2 shows on the ordinate the percentage gain or loss in conductance during hyperventilation for each of the five measurement sessions. While the two CPO subjects (Ba and Ma) showed similar EDC patterns for the experiment (Fig. 1), the reactivity of one subject (Ba) dropped during the maximum pressure phase of the experiment, tending to rise during decompression. The other CPO subject (Ma) showed little variation in his EDC response patterns to hyperventilation as the experiment progressed. Finally the physician (Bu) showed enhanced autonomic reactivity as compared to the pre-experimental control, with reversion to the control level just prior to the termination of the experiment (Measurement session IV). Apparently the ANS reactivity of one of the subjects decreased during the maximum compression period, and, similar to the curve for Bu, increased midway in the decompression period.

The lability of the ANS may be inferred both from the displacement during hyperventilation and the relative recovery during breathholding. Figure 3 shows the relative recovery of the three subjects during breathholding following hyperventilation.

As might be expected, the subject (Ba), who showed greatest variation in displacement indices during hyperventilation (Fig. 2), also showed the most

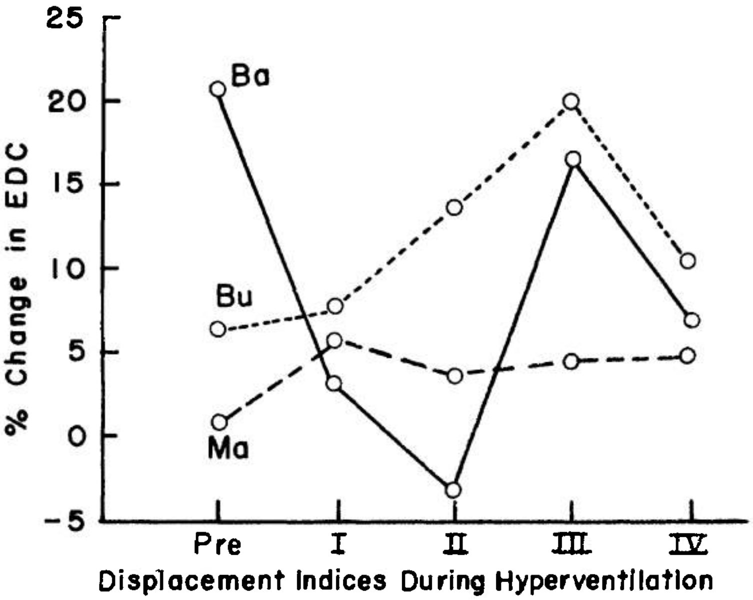

Figure 2. Displacement Indices During Hyperventilation

variation in terms of the relative recovery to EDC basal level following hyperventilation. Moreover the subject (Ma) who consistently showed little displacement to hyperventilation showed negligible relative recovery in any of the experimental sessions. Bu consistently shows relatively complete recovery for all of the measurement sessions.

One measure of ANS resiliency employed in previous studies utilizing EDC derived scores is the Recovery Quotient (RQ) (Weybrew, 1959, 1962 and 1964). This score is computed from the ratio of post-stress recovery to displacement from stress and is presumed to be indicative of the capacity of the ANS to regain homeostasis following displacement. Figure 4 contains graphs of the RQ's for the three subjects over the five measurement sessions.

The ordinate in Figure 4 represents the RQ scores which may be either positive or negative depending upon whether the direction of change during recovery is the same or opposite to the change observed during displacement. Utilizing EDC measures to hyperventilation and breathholding as used in this study, positive RQ's are associated with conductance drops and negative RQ's with conductance gains during breathholding. Therefore the more closely RQ approaches unity, the more complete is the EDC recovery. RQ's greater than unity suggest overcompensation.

Accordingly, for two of the subjects (Bu and Ba) over-recovery is the rule during all measurement sessions. The remaining subject (Ma) shows negative RQ's prior to and midway the high-pressure period but ample ANS resiliency at the beginning and end of the experiment. Coupled with the fact that this last mentioned subject showed comparatively low EDC displacement to hyperventilation (Fig. 2) and low EDC recovery to breathholding (Fig. 3), the tendency for negative RQ's suggests a less labile person in terms of ANS function. Incomplete recovery following the imposition of successive stressors

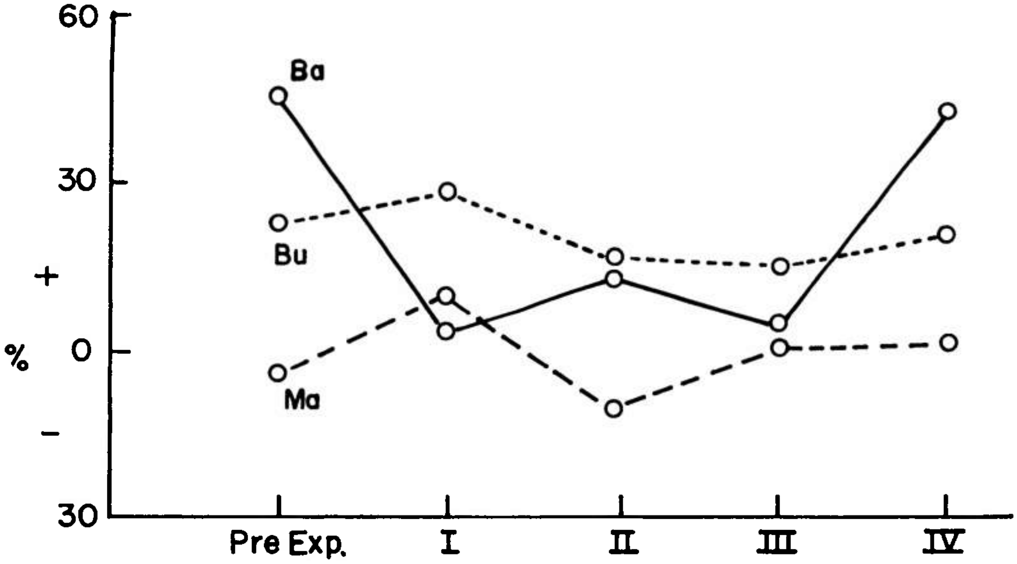

Figure 3. - Electrodermal Recorvery Index

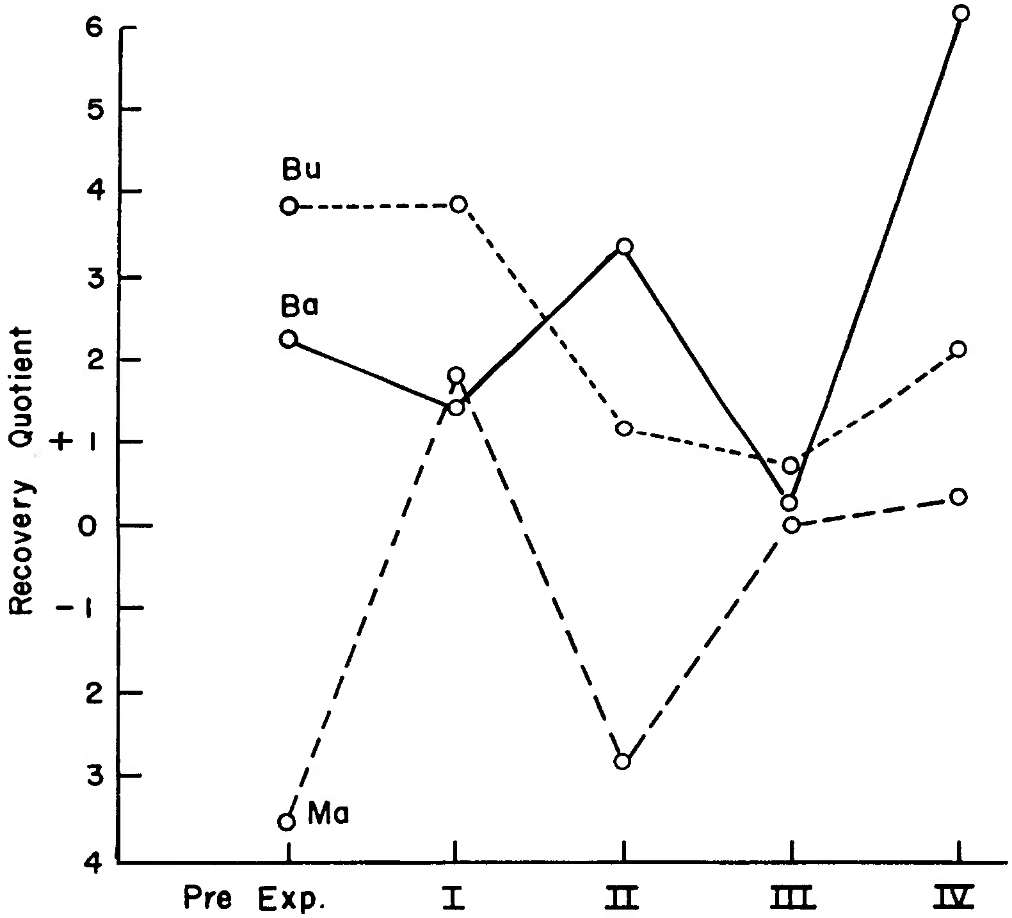

Figure 4. - Recovery Quotients for Each Measurement Session

has been suggested previously under the conceptual label of stair-stepping hypothesis (Weybrew & Alves, 1959). Validation of this syndrome, if indeed it constitutes one, with respect to the quality of adjustment to a prolonged stressful environment has not received significant empirical substantiation to date.

Previous research has indicated that another useful index of ANS recoverability may be derived from the slope of the EDC curve during breathholding (Weybrew, 1964). Differential rate of recovery is plotted in ohms/second for the successive measurement sessions (Fig. 5).

Almost without exception, the EDC curve during breathholding following hyperventilation is in the direction of decreased conductance (positive sign); however, for one subject (Ma) the opposite was seen as indicated by predominately negative slopes for the successive sessions. As compared to the pre-experimental control data, this index for two of the subjects (Ba and Ma) shows little variability during the experimental sessions. Though the meaning of the differences is obscure, the diametrically opposed recovery slopes (Ba positive and Ma negative) suggest individual differences in autonomic function, differences which may be related to differential adaptation to confinement in an exotic gaseous atmosphere. These differences in ANS recoverability become more suggestive when the disparity between these two subjects is viewed in terms of ANS responsivity to hyperventilation (Fig. 2).

For one subject (Bu), the slope of the resistance recovery curve reversed directions during the first experimental session, reverted to the control level for the second session and then dropped to a slower rate of recovery for the measurement sessions during the decompression period. It is interesting to note for this subject that the point at which he reached the lowest excitation level as defined by BL (Fig. 1) coincides with the point during the experimental session at which the slope reached the highest level. This finding suggests an inverse relationship between

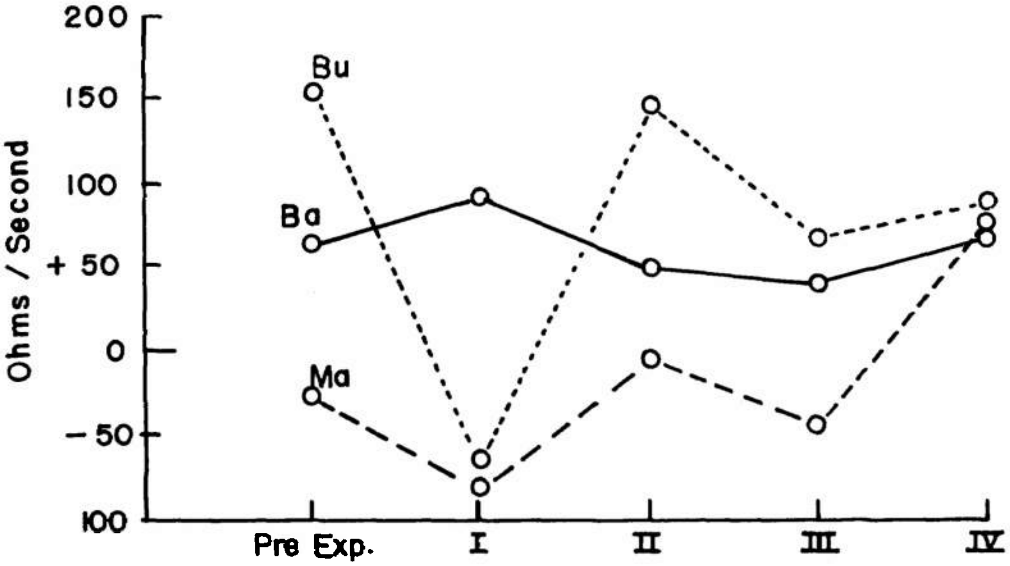

Figure 5. - Rate of Electrodermal Recovery During Breathholding

tension or excitation level and rate of recovery to basal level. However, previous research (Weybrew, 1964) involving a subject sample of approximately 200 men failed to show this inverse relationship. In fact there appears (op. cit.) to be a positive, though low, relationship between excitation level and the slope of the breathholding curve.

BREATHHOLDING

Breathing control has long been considered an essential part of the submarine escape training program. Hoff and Greenbaum (1954) have integrated the literature pertaining to breathholding as it relates to submarine escape. Alvis (1951) found that his subjects were able to hold their breath after breathing air for longer periods and to higher alveolar carbon dioxide tension levels as the ambient pressure was increased to the equivalent pressure of 99 ft. sea depth. At pressures greater than 33 ft. depth, the above author considered that oxygen played no important role in limiting breathholding. However, Otis, Rahn and Fenn (1948) found that at high oxygen tensions the breathholding time was long, whereas at low oxygen tensions breathholding time was short.

In the present study, it should be pointed out that breathholding following hyperventilation constituted a technique utilized to induce Sympathetic Nervous System (SNS) displacement. Breathholding time per se was not at the outset of this pilot study, considered a relevant variable, particularly since it failed to correlate with a number of variables utilized in previous research (Weybrew & Alves, 1959; Weybrew, 1964). Nonetheless, breathholding time was, in this study, hypothesized to be affected by long exposure to a foreign gaseous atmosphere, by increased pressure, and by other conditions existing during the confined period. Figure 6 contains line graphs of the breathholding data.

In the previous mentioned study (Alvis, 1951) it was hypothesized that the drive to breathe depended more upon carbon

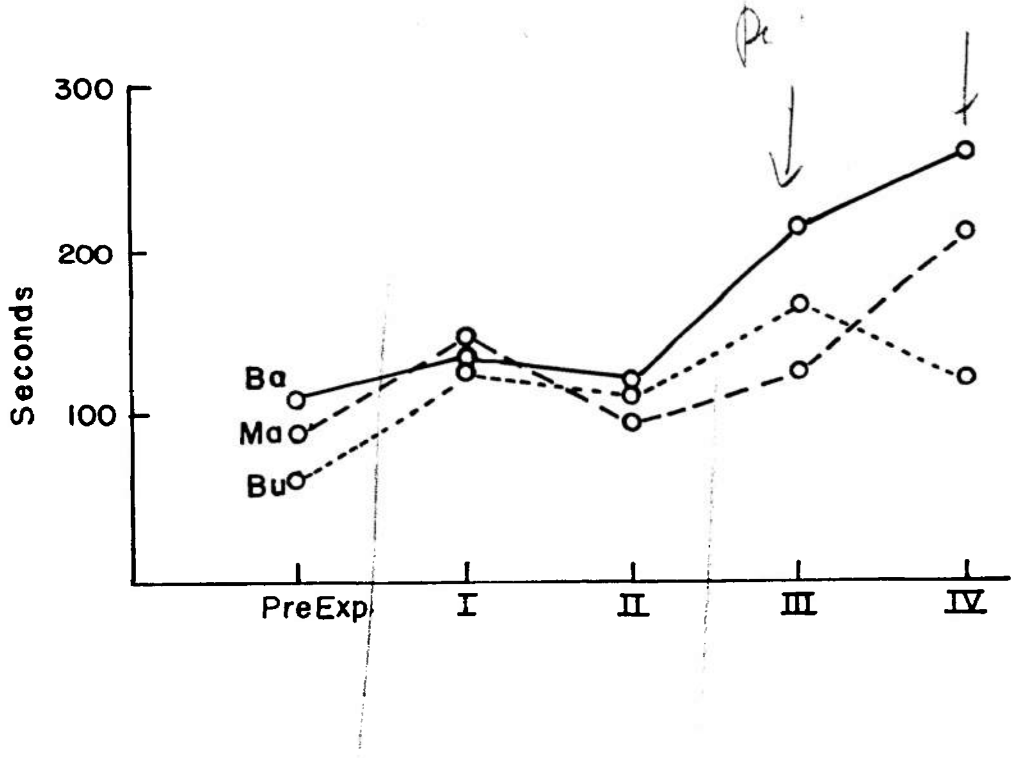

Figure 6. - Breathholding Time

dioxide accumulation and blood pH than upon oxygen depletion, particularly when the partial pressure of oxygen was of the order of 320 mm or greater (approximately 33 ft. sea level pressure). It should be reiterated that the present study involved breathholding time following hyperventilation whereas the previous study involved breathholding following the inspiratory phase of a normal breathing cycle. The principles of elementary respiratory physiology indicate that the "drive to breathe" is affected by the "bleeding out" of both oxygen and carbon dioxide during hyperventilation and is a monotonic function of the rate at which carbon dioxide accumulates during breathholding. At this time, the authors are not aware of a study examining breathholding time following hyperventilation as a function of increased ambient pressures.

The statistical check of the differences between the breathholding times of the three subjects over the five measurement sessions reached significance at the 4% confidence level (Friedman test, described in Wilcoxin, 1949). The mean of the pre-experimental breathholding times was 86.6 seconds and is comparable to that obtained by a group method of recording breathholding which resulted in a mean of 88.0 seconds (N=676 enlisted submarine candidates, Weybrew & Youniss, 1960). It is interesting to note that the breathholding times obtained at maximum pressure did not deviate significantly from the pre-experimental control levels but during decompression, specifically in decompressing from 88 PSI to 62 PSI, breathholding times increased significantly. This trend towards increasing breathholding time was maintained for two subjects in the final measurement period when the chamber was virtually at surface pressure.

The explanation of these results is not immediately evident. The increase in breathholding time for all three subjects from experimental session II to III however coincides roughly with an increase in the ambient partial pressure of oxygen (see Table I).[4]

The explanation for increased breathholding time for two subjects 16 hours later when the chamber was virtually decompressed, of course, cannot be explained on the same basis. Although the explanation of these results is probably to be found in the pCO_2 (partial pressure of carbon dioxide) in the alveoli themselves,[5] it seems both plausible and relevant that since breathholding is voluntary behavior, that changes in motivation coinciding with what has been called the "end effect" may be a contributing factor to the inordinately long breathholding times reported by two of the subjects in the post-experimental measurement session. Apart from the fact that he was the only one of the three subjects who had not served as a subject on previous helium studies, there is no immediately apparent explanation for the differences in the breathholding trend during decompression shown by one subject (Bu).

TIME ESTIMATION

Individual differences in estimates of the passage of time appear to be an interesting and perhaps relevant perceptual dimension. Errors in time estimation apparently tend to be positive for void intervals and negative for task-filled intervals and to be negative during states of induced muscular tension (Weybrew, 1963). The technique in this study was simply to ask the subjects to indicate following a signal when they

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[4] An increase in oxygen tension during decompression seems paradoxical. However, approximate calculations show $pO_2 = 160$ mm. during session II and 277 mm. during session III (Table I).

[5] Alveolar pCO_2 data were not collected at the exact time the electrodermal measures were taken.

judged 90 seconds had passed. The data in Figure 7 shows the percentage error in time estimation for the three experimental periods and the one post-experimental control (Measurement session IV). Unfortunately accurate time estimates were not obtained during the pre-experimental control period.

In the absence of pre-experimental control data little can be said about the graphs in Figure 7 except that during the presumably most monotonous period, midway during the prolonged 244 hours at maximum pressure (Session II), there appears to be a tendency for increased positive time errors for two subjects at least (Ba and Bu). For the same two subjects, there appeared to be a tendency to revert to negative time errors when the decompression period started. Finally, as the termination of the experiment neared the perceived passage of time slowed down and greater positive errors resulted.

PROBLEM SOLVING INVOLVING SPARTIAL RELATIONS

The Minnesota Paper Form Board Test was administered prior to and after seven days' confinement in the compression chamber, parallel forms being used for the two administrations. The Minnesota Paper Form Board Test is essentially a problem solving test involving the integration of geometrical forms. The response technique consisted simply of locating among five choices the one integrated form which results from a combination of the pieces in the test figure. The score is the sum of the correct choices made in the allotted time of 20 minutes (See Appendix A).

The results showed that all three subjects performed above the mean reported

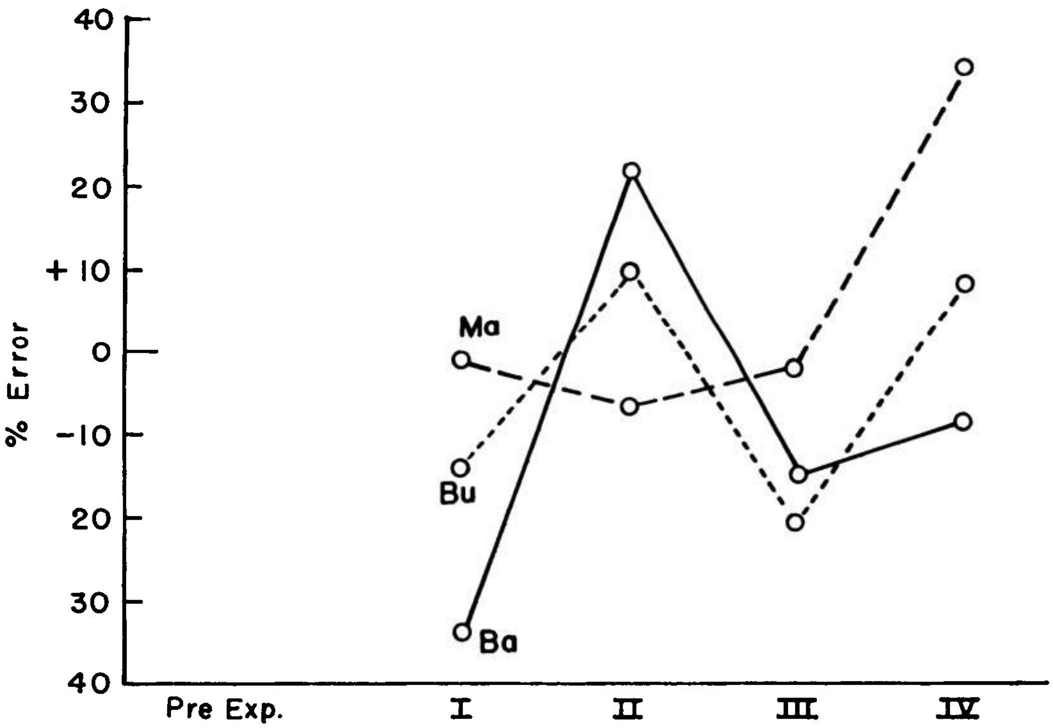


Figure 7. - Time Estimation Errors

in the normative data based upon an industrial population. One subject (Bu) scored well above the 80th percentile relative to the same normative data. There were no significant changes from one administration to another, suggesting that confinement and/or the effects of breathing the exotic gases were not "tapped" by this particular test instrument.

SUMMARY

This brief pilot study involved the confinement of three human subjects to a recompression chamber with a helium, oxygen and nitrogen atmosphere maintained at approximately seven atmospheres pressure for a period of 284 hours. The two rather broad goals of this exploratory study were as follows: (1) The identification of possible psychological and psychophysiological changes resulting from the confinement to the hyperbaric, exotic atmosphere; and, (2) An attempt to ascertain possible personality and/or psychophysiological variables accounting for individual differences in quality of adjustment of men to these conditions.

The major class of variables utilized in this study were those involving peripheral indices of Autonomic Nervous System function, indices derived from Palmar conductance levels, changes, and recovery from hyperventilation and breathholding. In addition, time span perception of an interval of 90 seconds were evaluated for four of the five experimental data-collecting sessions. Finally, one control and one experimental administration of the Minnesota Spatial Relations Test was completed in order to ascertain the likelihood of changes in spatial perceptual processes possibly resulting from rather limited viewing distance provided by the experimental chamber.

With a population sample of only three subjects, tests of significance of differences between measurement periods are at best only suggestive. Nevertheless, the significance of the between-sessions differences were evaluated by the nonparametric significance test described by Wilcoxin (1949). The results of this statistical test suggested that none of the differences among the four experimental sessions and the one pre-experimental control session were significant (20% confidence level) for any of the variables except breathholding time (Fig. 6). Tentatively, therefore it appears that if the particular measures utilized in this experiment were applied to a larger population exposed to the same experimental conditions there would be relatively few significant changes as a function of time in the experimental conditions. This statement does not hold, of course, for the differential breathholding time, although these authors are not able to ascertain the relevance of the finding that breathholding times are different for different conditions of pressure, confinement and gaseous composition. In short, therefore, the first general goal of this pilot study, i.e., to identify relevant variables sensitive to the psychophysiological and psychological effects of confinement to the conditions existing during this experiment, was not fully accomplished by this study.

The second goal pertaining to the identification of those adjustment processes accounting for individual differences in the adaptation to these conditions may have been slightly clarified by the results of this study. First, in terms of peripheral indices of Sympathetic Nervous System reactivity (general excitation level) the two CPO subjects (Ba and Ma) showed virtually identical control and experimental patterns (Fig. 1). These two subjects showed a pattern of ANS indicators suggestive of moderately low excitation level at the beginning and end of the experiment with a relatively heightened excitation level occurring midway during the maximum compression period, session II of the data collection schedule (Table I). Conversely, the Submarine Medical Officer subject (Bu) showed heightened excitation level prior to, and just before termination of the experiment with a trend towards relaxation midway during the experimental period. Secondly, in terms of autonomic reactivity, the two subjects (Ba and Ma) who showed similar excitation level patterns showed quite dissimilar ANS reactivity patterns (Fig. 2). The subject, Ma showed very low reactivity throughout the experiment whereas Ba showed extremely high reactivity in the control session dropping to a very low reactivity level midway during the experiment. Again, Bu showed quite dissimilar reactivity patterns as compared to either of the two other subjects. In terms of ANS recoverability one subject (Ma) who showed consistently low reactivity (Fig. 2) also showed low recoverability as compared to the remaining two subjects (Fig. 3). Also, in terms of recoverability rate (Fig. 5) and the index of recovery relative to displacement (Fig. 4), all three subjects appeared to be quite different. Accordingly, for Ba and Ma while showing rather similar patterns of recoverability rates (slopes) the RQ's over the measurement sessions are nonetheless quite different since the slopes and RQ's of the two curves tend to be in opposite directions, Ba positive and Ma negative. The remaining subject (Bu) on the other hand, though showing a somewhat erratic pattern for both slope and RQ's, nevertheless suggested a consistent tendency toward overrecovery of conductance changes during breathholding.

In short, the indices of autonomic function obtained from scores derived from palmar conductance measurement before and during the experimental period suggests only that there may be significant individual differences, though with only three subjects involved, little can be said about the relevance of these differences in these score patterns. This is true particularly since, insofar as concensus judgment is concerned, all three subjects adapted optimally to the experimental conditions with no remarkable sequelae. Several of these scores however appear to be sensitive to the conditions imposed by this experiment inasmuch as differential, between-person change-patterns may have been demonstrated (first 5 Figs.). As additional data accumulate, these or similar measures may turn out to be significant indicants of individual differences in the quality of adjustment to the conditions of confinement and exposure to exotic gaseous atmospheres.

The breathholding time curves in Figure 5 suggest significant increases in breathholding time following hyperventilation as decompression began. Though contrary to certain findings in the literature (Alvis 1951) it was suggested that this increase in breathholding time may have been due to concomitant increase in oxygen partial pressure. More likely perhaps according to certain findings in the literature (op. cit.) is the possibility that increased breathholding times resulted from differential carbon dioxide tensions as the decompression proceeded. One plausible psychological explanation of these findings is that the individual motivation to perform well on the assigned tasks, in this case breathholding, increased as the termination of the experiment approached. Of course this increase in motivation coinciding with the termination of the experiment assumes a corresponding depreciation in motivation preceding the last two measurement sessions. All of these explanations are presented as hypotheses which are amenable to test by appropriate experimentation.

REFERENCES

1. Alvis, H. J. Breathholding breakpoint at various increased pressures. U.S.N. MedResLab Report No. 177, 1951.
2. Friedman, M. The use of ranks to avoid the assumption of normality. J. of Amer. Statist. Assoc., 1937, 32, 675-701.
3. Hoff, E. C., & Greenbaum, L. J., Jr. A bibliographical sourcebook of Compressed Air, Diving and Submarine Medicine, Vol. 2, Washington, D. C.: ONR and USN Bureau of Medicine and Surgery, 1954 (page 251).

4. Otis, A. B., Kahn, H. & Fenn, W. O. Alveolar gas changes during breathholding. Amer. J. of Physiol., 1948, 152, 674-686.

5. Rotter, Julian B. & Rafferty, Janet E. Manual for Rotter incomplete sentences blank - College form. New York: The Psychological Corp., 1950.

6. Schaefer, K. E. Experiences with submarine atmospheres. J. Aviation Med., 1959, 30, 350-359.

7. Weybrew, B. B. Behavioral Energetics: I. A Factor Analytical Study of Individual Differences in Modes of Energy Discharge resulting from Experimentally-induced Frustration. U.S.N. MedResLab Report No. 378, 1962.

8. Weybrew, B. B. Accuracy of Time estimation and muscular tension. Percept. mot. Skills, 1963, 17, 118.

9. Weybrew, B. B. Prediction of adjustment to prolonged submergence aboard a Fleet Ballistic Missile Submarine: IV. Psychophysiological Indices, U.S.N. MedResLab Report No. 416, 1964.

10. Weybrew, B. B. & Alves, D. An exploratory study of the relationship of autonomic resiliency to manifest anxiety and selected personality traits. U.S.N. MedResLab Report No. 307, 1959.

11. Weybrew, B. B. & Youniss, R. The relationship of breathholding ability, manifest anxiety, and past aquatic experience to performance in the pressure chamber and escape training tank. U.S.N. MedResLab Report No. 329, 1960.

12. Wilcoxin, F. Some rapid approximate statistical procedures. American Cyanamid Co., 1949.

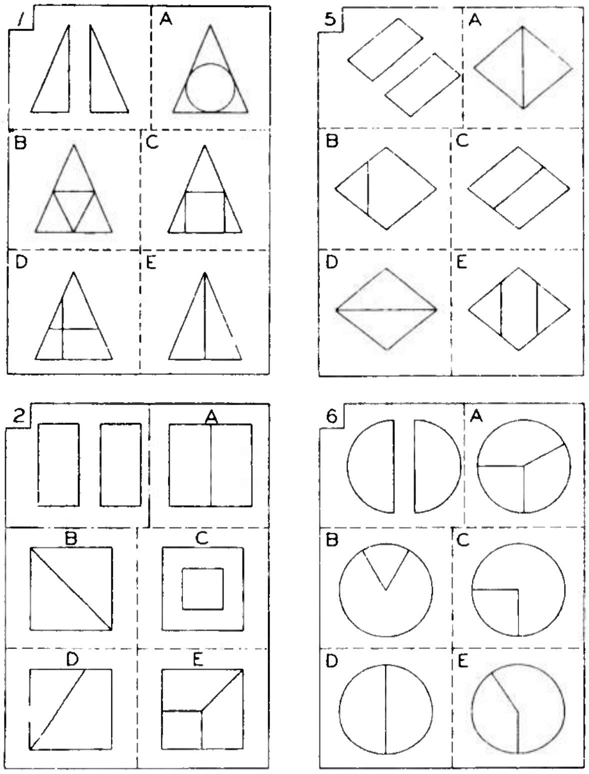
13. Woodworth, R. S. & Schlosberg, H. Exp. Psychology, New York: Holt, 1954, Chap. 6.

14. Hanna, T. D. A physiologic study of human subjects confined in a simulated space vehicle. Aerospace Med., 1962, 33, 175-182.

15. Workman, R. D., Bond, G. F. & Mazzone, W.F. Prolonged exposure of animals to pressurized normal and synthetic atmospheres. U.S.N. MedResLab Report No. 274, 1962.

16. Lord, G. P., Bond, G. F. & Schaefer, K. E. Pulmonary function in man breathing helium, oxygen, and nitrogen at 7 atmospheres absolute pressure for 12 days. Federation Proceedings Am. Physiol. Soc., Spring, 1964.

APPENDIX A



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