Performance and Habitability Aspects of Extended Confinement in Sealed Cabins

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THE SUCCESSFUL launching of artificial satellites has sharpened the focus on several parameters in human psychophysiologic stress. Isolated in an entirely new physical world, future space crews will have little control over outer conditions, much to think of, and little to do. Although man has survived long term confinement in relatively small spaces, he has not been required to exhibit high level precision performance and few parameters in this area have been extensively investigated. Recent studies[1,3] on the efficiency of performance of persons confined to small spaces wherein sensory stimulation is minimized indicate that decrements in performance and various abnormal phenomena, for example, hallucinations, may occur. With the possibility of space travel and flight in nuclear-powered aircraft which might require confinement for weeks or months, an imminent event studies of physiologic and psychologic functioning of the human organism for extended periods of time are urgently needed. Furthermore, with an increase in oxygen concentration of the air beyond that used at sea level, greater possibilities for behaviorial decrements are present. This study represents a phase of the above problem and was undertaken to determine the effects on performance of six men during seven days of confinement in a small area at a simulated altitude of 10,000 feet with an oxygen concentration equivalent to 55 per cent at sea level.

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PROCEDURE

Confinement Area Environment. — The confinement area in which the six subjects lived for seven days consisted of two compartments, a work chamber and a leisure chamber, with single one-way viewing ports located at each end (Fig. 1). Personal gear, diet, performance and monitoring procedures as well as the layout of the two compartments and photographs of the confinement area have been previously reported.[2,5,6] Three work stations were included in the work area; two were located side-by-side with the third across from these two. To the right rear of this latter station was a food heating unit.

The leisure area contained two bunks, 27 by 62 inches, attached to the wall, a flush-type toilet, individual urinals located in the access hatch, a collapsible wash basin, a small bench attached to the wall, and a table in the center of the chamber. A curtain

was available to screen off the toilet area for privacy. Storage shelves and small bins were available for the storage of personal articles.

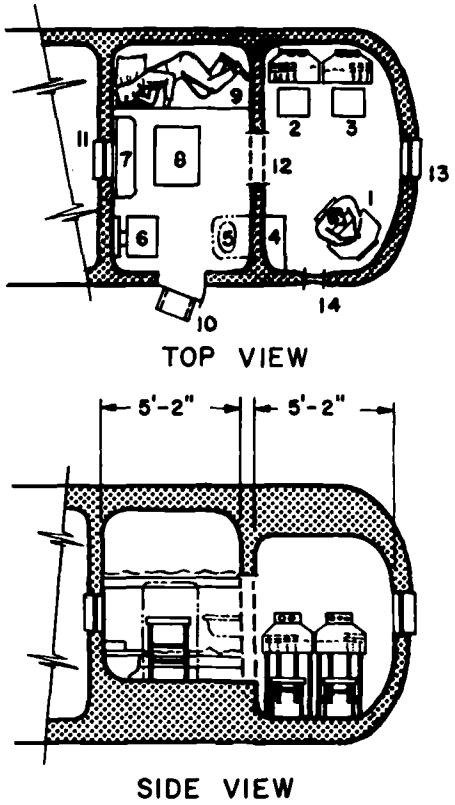

Fig. 1. Drawing showing the various areas of the confined space: test station (1, 2 and 3), food heater (4), drop-type sink (5), toilet (6), bench (7), table (8), bunks (9), access hatch (10), one-way viewing ports (11, 13), door-way (12), and control cable entrance port (14).

The total floor area of the entire confinement chamber, the leisure area, and the work area was 73, 38, and 35 square feet respectively; total free area was 33, 18, and 15 square feet, while the volumes were 448, 211, and 237 cubic feet, respectively, or about 75 cubic feet per man. The floor level of the work space was 17 inches lower than that of the leisure area. This differential height was intended to emphasize the differences in functional aspects of the two chambers. Ceilings and walls were padded with decorative noise-reduction panel blocks of Celotex. In the leisure area, the floor and walls, up to 40 inches in height, were painted dark brown; the ceiling and walls above this point, light brown. The same arrangement was followed in the work area with dark and light green paints being used. The food for each subject for the trip was contained in seven boxes, each box including food for one day. A disposal unit was located beneath the floor of the leisure area to handle the elimination of food residue, or trash, and was accessible by means of a trap door.

Psychologic Processes Sampled. — For a study of this nature, it appears desirable to determine the psychologic processes or functions to be sampled, select tests or tasks which have been indicated by factor analysis to have high or moderate loadings on these psychologic functions, or tests validated by the construct validity approach, and administer these tasks to a sample of subjects to determine factorial content and reliability aspects. Each subject would be matched with another subject according to similarity in selection criteria and in preflight performance on the test battery. A group including one of each pair would serve as a control while the second member of each pair would be placed in the experimental group.

Because of time and cost limitations,

it was necessary to modify this procedure. Tasks which were readily available were included to sample various functions. The performance tasks during the confinement period. In addition, an intellectual aptitude test with two equivalent forms was administered before and after the run. Fol-

TABLE I. PERFORMANCE TASKS

Location	Tasks	Description
Station 1	Maintaining pointers of three dials at null point.	Two simultaneous visual tracking tasks.
	Reacting to onset of visual warning indicators.	
Station 2	Maintaining pointer of dial at null point.	Two simultaneous visual tracking tasks. Periodically, auditory task imposed to increase the number of simultaneous tasks to three. The auditory task involved comprehension of prose passages on various topics and required the subjects to make inferences beyond the material presented.
	Reacting to onset of visual warning indicators.	
	Attention to details of prose passage imposed aurally.	
Station 3	Arithmetical reasoning test.	Required subjects to manipulate numbers using algebraic addition multiplication, and squaring operations by means of configuration and color of lights on panel. Subject also required to shift quickly among three methods with the above operations. Concerned with arithmetical flexibility.
	n Alternatives test (paper and pencil test).	Concerned with ability of subjects to learn associations with single or multiple alternatives.
	Multiple solutions test (paper and pencil test).	Concerned with intellectual flexibility, i.e., the ability to extract information from a stimulus situation in which multiple information abounds.
Leisure area	Weight discrimination.	Concerned with ability to discriminate seven small cubes differing slightly in weight.
	Time estimation.	Concerned with ability to estimate 90 second time intervals.

may be grossly divided into three groups according to the psychologic processes involved: (1) performance at stations 1 and 2 (except for the auditory task) consisted of relatively simple, routine psychomotor tasks; (2) those tasks performed in the leisure area involved simple judgment functions; and (3) station 3 and the auditory task which tapped the more complex psychologic processes, that is, learning, thinking, and reasoning (Table I).

The tasks performed at the three work stations involved psychologic processes similar to those which would occur to a greater or less degree in most aircraft work stations. The tasks performed in the leisure area were utilized to obtain supplementary information concerning simple judgment or discrimination functions. In all, there were ten performance tasks

lowing the run a questionnaire concerned with habitability aspects during the confinement period was completed by each subject and a diary was maintained by each during the confinement period.

Subjects and Schedules.—The subjects were six navel enlisted men of the Air Crew Equipment Laboratory. No formal screening procedure was utilized in selecting the subjects. The major criteria were their observed ability to get along well with others and the willingness to abstain from smoking for seven days. The subjects were assigned to work shifts in pairs. Each pair was on stations 1 and 2 for four hours (two hours at each station), off eight hours, and then returned to stations 1 and 2 for another four-hour tour of duty. During one eight-hour rest period, the pair was

allowed to rest or sleep in the two bunks. During the other eight-hour period, each man spent approximately two hours at station 3. Washing, eating, and other activities were performed between duty at the various stations. The scheduled watches are shown in Table II.

TABLE II. SCHEDULE OF WATCHES AT STATIONS 1, 2, AND 3.

Time	Station 1	Station 2	Station 3
1200-1400	S_1	S_2	S_3
1400-1600	S_2	S_1	S_4
1600-1800	S_3	S_4	—
1800-2000	S_4	S_3	—
2000-2200	S_5	S_6	S_1
2200-2400	S_6	S_5	S_2
0000-0200	S_1	S_2	—
0200-0400	S_2	S_1	—
0400-0600	S_3	S_4	S_5
0600-0800	S_4	S_3	S_6
0800-1000	S_5	S_6	—
1000-1200	S_6	S_5	—

The leisure area tasks were performed three times a day, at 0400, 1200, and 2000 hours. The subjects worked in pairs, with each man administering, scoring, and timing the performance of the other.

RESULTS

Pre- and Post-confinement Tasks.—The six subjects were divided into two groups of three each and received reasoning test problems prior to confinement, and then during the last hour of the seventh day. Two tests were developed with thirty items in each. Ten of the items were numerical series; ten were arithmetical reasoning problems; and ten involved diagrammatical reasoning, all items being taken from standard psychologic tests. The two tests differed in degree of difficulty with form A being less difficult than form B. Each of these two tests was split into two, with five of each of the three types of items. Group 1 took A_1B_2 prior to confinement and A_2B_1 at the termination of the seven-day period. Group 2 began with B_1A_2 and finished with B_2A_1. This procedure allowed a counter-balancing of the difficulty variable. There were no significant differences between the pre- and post-confinement tests according to the analysis of variance; the only sources of variation which were significant were forms and subjects effects.

Station 1 Tasks.—The subject was given two simultaneous visual tracking tasks; he attempted to maintain the pointers of three dials at a null point and reacted to visual warning indicators by pressing a push button. Only the responses to the nulling operations were recorded. The amount of time in which one or more of the pointers were off the null position was recorded continuously by means of a digital precision timer. However, to avoid disruptions due to the changing of the men at the stations, only 100 minutes of the two-hour period were utilized, that is, from ten minutes after the beginning of the watch to ten minutes before the end.

In the analysis of this data, one interaction and all main effects were significant. The days x watch interaction effect contributed significant variance; however, performance on watch 1 was more effective than on watch 2 for all days. But the difference between the two watches was greater on days 1 to 3 than on days 4 to 6. Performance was best on days 1 and 6; moderate for days 2, 3, and 5; poor on day 4; and on day 7 a great decrement occurred in performance. This variation in performance on this station was probably due to the monotony of the simple tasks. Observation of the behavior of the subjects at station 1 and data obtained in the questionnaires and diaries tend to substantiate this interpretation.

Station 2 Tasks.—At station 2 the tasks were similar to those at station 1. There were two differences. Only one instrument dial had to be maintained at the null point. Also a third task, auditory comprehension of prose passages, was imposed by means of a tape recording for each subject once a day. The subject heard the passage twice and then completed a ten item multiple choice test on the subject matter. These tests were taken from the Iowa tests of reading comprehension.

The reaction time to the onset of visual warning indicators was recorded, whereas the nulling operation was not. The analysis of variance of the reaction time data indicated that subjects and all interactions involving subjects were significant, making generalizations difficult. The periods effect was significant also, with the best performance occurring on the first half hour, and the worst during the second and third periods. The days x watch x periods effect was significant, but no double interactions containing these effects appeared. The significant interactions containing subjects probably were an indication of boredom with these simple tasks since visual observations revealed symptoms of boredom, for example, talking with others and standing while performing a task. Because of these aspects, any definite conclusions derived from this analysis are tenuous.

According to comments elicited by the questionnaire, the auditory task was welcomed on station 2 because of the monotony of the other two tasks. Performance on this task was evaluated by means of a single Latin square design. The results of the analysis indicate that prose passages were the only significant source of variation.

Station 3 Tasks.—These tasks were of a more complex nature than those at stations 1 and 2 and were more absorbing of the subjects' attention. The motivation of the subjects toward these tasks appeared to be on a higher level than to the tasks of the other two stations, according to visual observations of the subjects working at the station and to their comments in the questionnaires and diaries. For the tasks at this station, alternate forms were provided and randomly assigned to practice and experimental sessions. There were twelve alternate forms for both the *n* alternatives test and the multiple solutions test (for five practice and seven experimental sessions); seventeen for the arithmetical reasoning test (ten practice and seven experimental sessions). The last two practice sessions were conducted in the chamber. The first of these was conducted under the actual experimental conditions of 10,000 feet with 55 per cent oxygen sea level equivalent present. The second was conducted in the chamber but at sea level atmospheric conditions.

The arithmetical reasoning test made use of a light panel consisting of four rows of five white lights, followed by a red light and a green light in the sixth and seventh columns of these rows. At the bottom of the panel were three red lights. For each problem one white light in each row, one red light in column 6, one green light in column 7, and one of the red lights at the bottom of the panel would be lit. The white lights indicated addition, subtraction or squaring, the red and green lights in columns 6 and 7 modified the procedure only for the row in which it appeared, and the red lights below indicated which of three mathematical operations should be employed. The subject knew in advance which method to follow for solving one-half of the problems; the other one-half of the problems were presented in a random order. A maximum of twenty seconds was allowed to solve each problem. Upon solving the problem the subject pressed a button to the left of the light panel which turned off the lights and permitted the experimenter to record the time. There was an interval of twenty seconds between problems during which the subject could write his answer on a score card. A bright warning light flashed two seconds before a problem was to appear.

The results of the arithmetical reasoning test using number of errors as the dependent variable revealed that the only sources which were significant were subjects and days. Even though the subjects had been practiced on this test for ten days prior to the beginning of the confinement period, a prac-

tice effect was indicated from day 1 to day 2. The variation between the remaining days was small.

The *n* alternatives test consisted of a one and a five alternatives symbol association test. The one alternative test contained four symbols, each of which was associated with one, and only one, number. The five alternatives test involved the use of the same four symbols. However, associated with each symbol were five numbers. The number to be associated with the symbol depended on the position of the symbol in a series and on which symbols followed or preceded the symbol. The sources which contributed significant variance were alternatives and days. As was expected, more correct responses were obtained on the one alternative test than on the five alternatives test. The performances on the first four days were similar; however, on day 5 an increase in the number of correct responses occurred which reached its peak on day 6, and then on day 7 fell to the same level as on day 5.

The multiple solutions test consisted of ten problems, each of which contained three 1 digit and seven 2 digit numbers selected from a table of random numbers. The task for the subject was to manipulate one or more of these numbers by means of any mathematical operation (addition, division, multiplication, squaring, et cetera) to obtain a 2 digit number which was selected also from a table of random numbers. For any problem, multiple solutions were possible and a three-minute time limit was allowed for each problem. Only subjects appeared as a significant source of variation.

Leisure Area Tasks.—The analysis of variance was used in analyzing the time judgments in which the dependent variable was the deviations from 90 seconds. However, a linear transformation of the data to remove negative numbers was performed prior to the analysis. The only source which was significant was days. From day 4 to day 7 there is an indication of increasing underestimation. This result suggests that with increasing time in confinement there is an accompanying deterioration of time orientation.

In the analysis of weight judgments, the only significant source of variation was subjects. There was some suggestion that the 0400 hours performance was inferior to performance at the other two periods; but these differences were not significant.

Questionnaire and Diary.—The questionnaire and diary were analyzed qualitatively to discern comments which appeared to be of major importance. These analyses indicated that:

1. The tasks at stations 1 and 2 were too simple and monotonous to maintain the interest of the men. However, the subjects stated that the complex tasks at station 3 were of such nature that their interest in doing well was maintained, and that these tasks were appreciated.

2. Stations 1 and 2 were too close and created distractions for both operators.

3. The chair designs required modifications to insure comfort.

4. Morale was high for about two days, decreased during the middle portion of the study, and increased during the last few days. The monotony of the schedule, and especially of the tasks at stations 1 and 2, was probably instrumental in producing some of the decrease in morale.

5. The taste and smell of some of the food was nauseating.

6. The leisure area was not usable by other than sleepers because the light required for leisure activities disturbed these men.

7. The bunks were not large enough for every man and resulted in loss of sleep by all men.

8. The temperature varied greatly within and between the two chambers. For example, it was warm in the work area while it was cold in the leisure area.

DISCUSSION

Unfortunately, true outer space conditions could not be duplicated in this experiment. The zero G state in free space flight will create severe psychophysiologic disturbances. The experience of no up or down, and the lack of convection as a mode of heat exchange will adversely effect the senses of orientation. Regulation of the cardiovascular system, and even digestion, are partially gravity-dependent.

Outer space is black, empty, and silent. The much discussed "break-off" phenomenon occuring after 80,000 feet and described as a sudden mixture of elation and sorrow, a feeling of remoteness, and a detachment from all that is worldly, cannot be adequately simulated in the laboratory. This stimuli-free situation, in which prolonged periods of stimuli deprivation and isolation, reduced activity and emotional restraint are required, is far different from laboratory conditions where man knows that someone is standing by outside ready to release him when conditions become too stressful.

Within this frame of reference, the results of this experiment would appear to indicate that the intellectual functions of subjects should not deteriorate over a seven-day period even though the environmental conditions are not optimum. This is in spite of the great variation in the simple psychomotor performance at stations 1 and 2. Performance on the seventh day of confinement was as effective as on the first day in the complex tasks, which seemed to have intrinsic motivation qualities. In some of the complex tasks, performance appeared to be more effective on the last two or three days than during the early days. This probably represents a practice effect or the development of "learning sets."

As stated above, the variability in performance on the psychomotor tasks of stations 1 and 2 probably represents symptoms of boredom. The behavior of the subjects observed through the one-way port and comments on the questionnaires and diaries makes this hypothesis more tenable. This variation would suggest the desirability of challenging the subject's ability by making the simple routine tasks less simple and routine, and supplementing these with more complex tasks which require higher level behavior. This aspect would appear to be more important if studies or actual flights requiring weeks or months are undertaken.

The significance of the watch effect in the analysis of the station 1 data is of interest. For all subjects, performance on the second watch was less efficient than on the first watch. The first watches fell between 12 noon and 12 midnight; the second watches, between 12 midnight and 12 noon. This result probably represents a conflict between the habitual diurnal cycle of the individual and the cycle required by the schedule during the confinement period, and suggests that a person cannot change his diurnal cycle quickly. Similar results have been reported by Kleitman[4] who emphasizes the desirability of matching the diurnal cycle with the requirements of the task.

The fact that these six subjects per-

formed efficiently under extremely rugged conditions indicates the adaptability of the human organism. However, it would appear that any deviation from optimum conditions would tend to be magnified with increasing time in the confinement area. Furthermore, seven days represents a small time period. Can the human organism perform as well if confined for thirty days, sixty days, or for one year? These time periods may be required for space flights of the future, or for duty within small space stations. The answer to these questions is a task for further research.

SUMMARY

In a simulated space flight, six naval enlisted men lived and worked in two small chambers maintained at 10,000 feet with an oxygen concentration of 55 per cent sea level equivalent for seven days. During this time each man worked at three stations for a total of ten hours, slept eight hours, and spent the remaining time for eating, working, recreation, and other miscellaneous tasks.

From the results of various tests and tasks, it appears safe to conclude that the intellectual and psychomotor functions of subjects, as sampled in this study, should not deteriorate drastically over a seven-day period even though the physical conditions are not optimum. However, it would appear that any deviation from optimum conditions would tend to be magnified with increasing time in flight. Furthermore, it was suggested that simple routine tasks should be made less simple and routine and should be supplemented with more complex tasks which require higher level behavior.

REFERENCES

1. BEXTON, W. H., HERON, W., and SCOTT, T. H.: Effects of decreased variation in the sensory environment. *Canad. J. Psychol.*, 8:70, 1954.
2. HENDLER, E., and MANCINELLI, D. A.: Environmental requirements of sealed cabins for space and orbital flights. Part 1: Introduction to a confinement experiment and description of the test chamber. Naval Air Material Center, Report No. NAMC-ACEL-383, August 27, 1958.
3. HERON, W., DOANE, B. K., and SCOTT, T. H.: Visual disturbance after prolonged perceptual isolation. *Canad. J. Psychol.*, 10:13, 1956.
4. KLEITMAN, N.: The sleep-wakefulness cycle of submarine personnel. In *A Survey Report on Human Factors in Undersea Warfare.* Washington: National Research Council, 1949.
5. LIBBER, L. M., SANTAMARIA, L. J., and TILLER, P. R.: Environmental requirements of sealed cabins for space and orbital flights. Part 4: Physiological changes produced in humans by prolonged confinement in an oxygen-rich environment. Naval Air Material Center, Report No. NAMC-ACEL-386, October 8, 1958.
6. MICHEL, E. L., and LANGEVIN, R. W.: Environmental requirements of sealed cabins for space and orbital flights. Part 2: Continuous exposure of human subjects to increased oxygen tension for seven days. Naval Air Material Center, Report No. NAMC-ACEL-384, September 10, 1958.