Study of Sensory Deprivation, Pain and Personality Relationships for Space Travel

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PROLONGED SPACE travel by man may require severe social restrictions, and stringent conditions of sensory and perceptual impoverishment. These conditions of space travel are similar to phenomena generally investigated in studies of sensory deprivation.

Studies in sensory deprivation have indicated many detrimental effects in performance due to impoverished sensory environment.[23, 25] It has often been reported that subjects in such studies experienced perceptual aberrations,[2, 6, 7, 22, 27] increased anxiety and feelings of insecurity.[8, 25] Performance on objective tests under reduced sensory input conditions has been found to be significantly reduced as compared to performance under higher level of sensory input.[12] It has been observed that motor coordination and the precision of motor performance is impaired.[27]

Given the information in the literature on the effects of sensory deprivation on performance, it appeared desirable to find ways to avoid degradation in performance so far as space travel was concerned without material change in design of spacecraft. Accordingly, it was hypothesized that the ability to withstand conditions of sensory deprivation might be a normally distributed characteristic similar in its distribution to other human characteristics. A number of studies provided evidence for such a point of view, since it was reported that some subjects "hallucinated" and developed emotional reactions within a few hours after being placed in impoverished perceptual conditions, while others, under the same conditions, experienced few or no incidents of imagery.[1] Another hypothesis advanced by Petrie[20, 21] seemed attractive, namely, that sensitivity to pain is negatively correlated to sensory deprivation sensitivity and positively correlated to certain personality variables.

This line of reasoning led to an hypothesis as to the nature of the problem and its solution for space travel: Since there appears to be an inverse relationship between sensitivity to pain, personality and performance under reduced sensory input conditions, men ought to be selected who are most sensitive to pain because they would be able to endure reduced sensory input conditions for a long time without degradation in performance; while conversely, those who could stand pain for a long time could not endure reduced sensory input conditions and would show abnormal performance.

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Specifically, the objectives of the present study were to:

(1) Correlate the ability to endure pain with the personality variables of the Minnesota Multiphasic Personality Inventory (MMPI) and the Edwards Personal Preference Schedule (EPPS).

(2) Correlate particular personality variables of the MMPI and the EPPS and the ability to endure pain with the ability to endure sensory deprivation.

(3) Assess the value of the MMPI and the EPPS and pain endurance tests as predictors of ability to endure sensory deprivation.

METHOD

The study of sensory deprivation, pain, and personality relationships for space travel was conducted in two phases: a first phase in which subjects were found, tested and selected for participation in the sensory deprivation studies, and a second phase in which paired subjects were retested for pain endurance and placed under conditions of reduced sensory input in a model multi-man space capsule.

Two groups of subjects participated in the study. One group of 33 subjects was composed of ministerial students enrolled at the Union Theological Seminary, New York City; another group of 29 subjects were made up of noncommissioned officers, except for two commissioned officers, of the U. S. Air Force, 773rd Radar Squadron, stationed at Montauk Point, N. Y. The Seminary Group ranged in age from 21 to 37; mean age was 23.8 years. The Montauk Group age range was from 19 to 43*; mean age was 28.6 years. The age range for the total group was from 19 to 43 years; mean age for the total group was 26.9 years.

So far as education was concerned, the mean years of education for the Seminary Group was at least 18. The mean years of education for the Montauk Group was 12.1. There was very little variation around the mean for either group. The mean for the total group was 15.3 years.

All subjects were volunteers who agreed to participate in the study. They appeared to be well motivated.

Twenty-four subjects were selected for further study from the Seminary and Montauk groups. The subjects were studied in pairs, homogeneous with respect to pain

* One man, age 51, was eliminated from consideration.

endurance. They reported for study according to a schedule which required two studies per week.

Three pain tests were administered to all subjects. The tests were an Ischemic Contraction Test, a Thermal Matching or Heat Test, and an Iontophoresis Test. All tests were administered according to standard procedures. The pain tests were applied at the time of selection, and the same tests were repeated under controlled laboratory conditions. There was no significant difference between these two applications. Test-retest reliability coefficients for these tests with tests administered mainly to samples of subjects employed by the Republic Aviation Corporation, no sooner than a week after the first administration, were:

Ischemic Contraction Test—Left Arm	.83
Iontophoresis Test—First Administration	.90
Heat Test—Left Arm	.67

The test procedure was as follows:

The Ischemic Contraction Test:—The subject was instructed to raise his arm over his head. After ten seconds, a sphygmomanometer cuff was applied to the upper arm and maintained at no less than 180 mm. Hg pressure. With the cuff inflated, the subject was required to contract his hand against a fixed resistance once per second, in time to a metronome, until pain and/or inability to continue forced him to stop. He was scored on the number of completed contractions.

The Iontophoresis Test:—The subject placed his arm on a pad saturated with saline solution, and a small ring containing a solution of KCL was strapped against the top of his forearm. The pad and the ring were wired to an electrical power source, (d.c. –45 volts) and a current from 0-50 milliamperes was passed through the arm at a rate which increased 1 milliampere every three seconds. The degree of pain was proportional to the current applied, independent of resistance. The subject was instructed to ask that the test be halted when he felt that he had reached the point of maximum endurance. The recorded score was the maximum number of milliamperes applied at the time the test was halted.

The Thermal Matching or Heat Test:—Similar areas on both forearms of the subject were painted with black india ink. The left arm was exposed to an infrared heat source 150 $Cal/sec/cm^2$ for ten seconds through an 8 cm^2 opening, producing approximately a 2 dol pain (47.2° C). Then the painted area of the other arm was exposed to a similar stimulus and the subject was instructed to report when the pain intensity he experienced felt equal to the pain induced by the first stimulus. The recorded score was the reported time to heat match to the nearest tenth of a second of the second heat exposure.

Pain Tests and Electrocardiogram Recordings:—When the pain endurance selected subjects arrived in the laboratory to serve in the sensory deprivation studies they were re-administered the Iontophoresis, Ischemic Contraction and Heat Tests. In conjunction with such administration, appropriate leads were placed on the chest of each subject and an ECG recording of the heart was made.

Additional laboratory tests were used in this study.

The Motor and Perceptual Motor Tests:—Before and after the stay under reduced sensory input conditions, three motor and perceptual motor tests were administered to the pain endurance selected subjects. The three tests in order of administration were: a) The Gross Motor or Rotary Pursuit Test, b) The Time Estimation Wheel Test, and c) The Fine Motor, or Telegraph Key, Tapping Test.

The Gross Motor or Rotary Pursuit Test:—The subject stood in front of a phonograph turntable rotating at 60 rpm and modified to incorporate a ¾ inch diameter brass target placed approximately two inches from the perimeter edge. He held a stylus in his hand with his arm flexed. When he received a signal to begin striking at the target, he brought his arm down and tried to hit the brass target each time the target appeared in front of him, i.e., one time per second. The score for each subject was the number of hits made in 30 seconds.

The Time Estimation Wheel:—The subject stood before a vertical square, white plane approximately 24 inches x 24 inches from which the upper right quadrant had been removed. A similar complete plane, separated from the front plane by about an inch, made a small box. When the subject depressed a spring-loaded button, a clock-type pointer within the box revolved about a point bisected by the diagonals of the square. The subject was allowed to see the pointer travel across the open quadrant and judge its rate of travel. His task was to judge the rate of travel as the pointer revolved and to take his finger off of the switch or button in time to stop the pointer immediately under a black line of the same thickness as the pointer. The pointer radiated from the center of the square to the perimeter at about –10 degrees from the vertical in the left upper quadrant. The subject was allowed five trials, and the score was the plus or minus deviation from the black line in degrees. The scoring grid was visible to the examiner, but not to the subject. The equipment was so designed that the motor stopped within approximately 0.15 second after power was interrupted.

The Telegraph Key Tapping Test:—The subject placed his hand on the table in position before a telegraph key so that his index finger was free to strike at the key. He was instructed to strike the key as quickly and as often as he could until told to stop. The test duration was 30 seconds. The score was the number of recorded taps.

The subjects were permitted to familiarize themselves with all tests before they began both pre- and post-tests of the sensory deprivation experiment.

The subjects rested on separate contour couches * in a full scale model of a multi-man space capsule. The contour chairs were separated by a table with a vertical partition parallel to the long axis of the contour chairs which divided the table into two equal parts, one for each subject, and served to prevent physical contact between the subjects. Each table had a top and two lower shelves with the top arranged for racks for each subject for storage of a water bottle fitted with a glass tube and a similar bottle containing a liquid food. A microphone, part of an ear defender communication

* Provided on loan by the Contour Chair Co., Inc., New York, N. Y.

system, rested on the table beside each man. On the lower shelves, urinals, bed-pans, and toilet paper were stored for each man. Two plane mirrors were hung to reflect the image of each of the subjects back to the open door of the cabin where an observer was stationed at all times.

Outside the cabin, arranged about the observer, were a 6-channel Sanborn Recorder, a Brown Self-Balancing Potentiometer, a Visoscope and an Ampex tape recorder. Written records were kept of water and food intake as well as urine and fecal output. The tape recorder was used to record all communications and observations made by the observers.

Prior to entry into the model space cabin all subjects were prepared for recording of EEG, ECG, GSR and rate of respiration (thermistor beads with nose clip) by appropriate attachment of sensors and leads to each subject, and systematic records of all of the readouts were made through the course of the experiments.

The subjects could communicate with the observer at any time during the experiment, but the observer only responded when a subject requested termination of his stay in the cabin. All subjects were given the idea that they should communicate whenever there was something to report, no matter how trivial it might seem, but care was taken not to suggest any type of content to the subjects.

Each subject donned ear defender headsets with built-in ear phones such as are typically worn by workers at air fields. White noise was fed into the headsets at a low decibel load sufficiently above ambient noise to shut out any orientation to the world outside, yet the subject obviously had monotonous and continuous hearing stimulation. The subjects wore goggles modified to allow light to come through translucent but not transparent lens surfaces. Thus, the subjects were visually stimulated by incandescent light which always illuminated the cabin, but the illumination was unchanging and unpatterned. The subjects wore heavy leather gloves, similar to those worn by electric arc-welders, and they were instructed to keep the gloves on at all times. Thus sensations normally received by the fingers and hands were diminished, and the threshold for discriminable patterns of sensation was raised. This tended to make sensory inputs from the hands monotonous. Similarly, the subjects wore heavy wool socks to diminish sensory input from the feet.

Because of the attached sensors and wires, the movement of the subjects was restricted. They were instructed not to leave their contour chairs and advised that the electronic wiring allowed only limited movement. Thus, the subjects could only turn from side to side, flex and unflex their limbs, sit up or lie down.

The food, Sustagen, was a bland, high caloric liquid, neither markedly pleasant nor unpleasant in taste. The subjects were encouraged to take nourishment whenever they desired, but when they did so, to take at least several ounces of the liquid. Thus oral stimulation tended to be minimized. The observers made sure that food did not remain in the racks without change for more than eight hours, and they maintained a close watch to ensure that food and water were always available.

A standard operating procedure was used which contained instructions to the experimenter and information which he read to the subjects while they were being trained in procedures to be followed during the experiment. A structured interview was used to question all subjects on termination of the experiment.

RESULTS

The results of the sensory deprivation study follow in sequence, in two phases, in the order that the study was conducted.

PHASE I—Pain Endurance Studies for Selection:— Table I shows the means and standard deviations on the pain tests for the Seminary, Montauk and Total Sample Groups; hereafter the Seminary Group will be designated the S group and the Montauk group will be called the M group.

The analyses of these mean differences showed that except for the Heat Test-Right Arm, mean difference (significant at the .05 level), there were no significant differences between the sample groups on the tests. One logical explanation of the apparent spread in means and standard deviations for most group comparisons might be that these differences were due to variation from sample to sample and the size of the samples.

The intercorrelations of the variables, in general, show high relationships between similar tests and low relationships between the tests. Therefore, it was concluded that the subjects for Phase II of the study should be selected on the basis of their performance for the left arm and 1st Administration on all three pain tests.

TABLE I. MEANS AND STANDARD DEVIATIONS FOR THE PAIN TESTS OF THE S AND M, AND TOTAL SAMPLE GROUPS

Test	SCORES								
	S			M			Total Sample Group		
	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.
Ischemic Contraction Test Left Arm	27	232.6	75.7	29	263.6	112.0	56	233.7	79.4
Ischemic Contraction Test Right Arm	31	234.8	39.0	29	233.9	83.0	60	234.3	63.0
Iontophoresis Test 1st Administration	30	21.2	5.3	29	21.5	10.3	59	22.1	7.6
Iontophoresis Test 2nd Administration	30	21.8	5.0	29	21.5	10.2	59	21.7	8.0
Heat Test—Left Arm	31	16.4	4.3	29	12.5	3.1	60	14.4	4.3
Heat Test—Right Arm	30	17.3	4.2	29	11.4	2.0	59	14.6	4.6

TABLE II. MEANS AND STANDARD DEVIATION ON PAIN ENDURANCE TESTS BY EXPERIMENTAL GROUPS

Tests	Pain Endurance Groups High Mean	S.D.	Medium Mean	S.D.	Low Mean	S.D.
Ischemic Contraction Left Arm	334.2	10.9	213.0	23.0	188.1	17.0
Iontophoresis 1st Administration	27.8	1.9	20.5	1.0	13.4	1.1
Heat—Left Arm	17.5	1.5	15.0	1.0	13.6	1.2

Thereafter, the deviation in standard deviation units from the mean on each test for each subject was computed. The deviations for all three tests were squared and summed for each subject and this total figure was the score for a subject. A positive or negative sign was added to the squared figures to indicate the direction of the variance. In a following step, the subjects were ranked from the highest positive total score through the null point to the highest negative summation score. This procedure yielded eight subjects who scored among the highest at the positive end, eight who were among the closest to the null point and eight who scored among the highest at the negative end, or a total of 24 subjects who were to be the primary experimental subjects.

An alternate "clinical" selection procedure was also conducted, based on the same evidence as that which provided the basis for the above rankings. When these selections were completed and the selections by this procedure were compared with the ranking procedures, it was found that the two sets of selected experimental subjects were practically identical. Twenty-three subjects of the planned twenty-four experimental pain endurance subject group served in the experimental sensory deprivation or Phase II studies.

Table II shows the means and standard deviations on the pain tests for the selected subjects of three experimental pain endurance groups. The difference between groups and the general homogeneity within groups as reflected in the standard deviations are clearly evident.

Analysis of the mean differences between groups by t test, showed that:

a). The experimental pain endurance groups were not significantly different, unfortunately, in performance on the heat test.

b.) The high pain endurance group was significantly different in performance in comparison to the medium and low pain endurance groups on the Ischemic Contraction Test. However, the medium and low groups were not different in mean performance with respect to each other on the Ischemic Contraction Test.

c.) All pain endurance groups were very significantly different from each other in performance on the Iontophoresis Test.

On the basis of the evidence, it appears that the group performances were confounded on the heat test, required some further discrimination between the medium and low groups on the Ischemic Contraction Test, and was highly discriminating in performance on the Iontophoresis Test.

Personality Test Studies a). *S and M Groups:*—All subjects of the S and M Groups were administered the Minnesota Multiphasic Personality Inventory (MMPI) and the Edwards Personal Preference Schedule (EPPS).

Comparison of the means of the S and M Groups with the MMPI Means and Standard Deviations indicated that the means for both groups were within normal limits, except for the S Group on the Mf scale for which the mean score appears almost plus two standard deviations from the mean. A similar comparison of means with the norms of the EPPS shows the S Group ORD mean score deviated more than minus one standard deviation from the EPPS mean score.

t test analyses of the differences between means on the MMPI and EPPS scales for the S and M Sample Groups showed that the S Group scored significantly higher on the K ($P = .05$) and the Mf ($P = .001$) scales. Ordinarily these sorts of differences would be interpreted as indicating that the S Group was defensive in reporting and significantly higher in their personality pattern with respect to feminine interests or esthetic personality qualities. The interests of the S Group makes such an interpretation less adequate than it appears in other cases. On the EPPS, the S Group scored significantly higher than the M Group on the AFF and NUR scales. These scores might be interpreted as indicating a greater propensity by the S Group than the M Group for expression of loyalty to people and a desire to help people. This would be a quite natural interest for future ministers.

On the other hand, the M Group showed significantly higher mean scores than the S Group on the ORD, EXH, ABA and CHG scales. These scores might be an indication that the M Group was more compulsive than the S Group and needed to find group support and acceptance in the eyes of others. They also seemed to need change in environment more than the S Group. This could have been a reaction to life on an isolated military base. Another explanation may be that they had a motivating force that led them to join the Air Force for travel and it also caused them to remain in the Air Force.

Selected Subjects on Pain Endurance Tests:—The MMPI and EPPS scores were analyzed for the subjects who were selected on the basis of their performances on the pain endurance tests. From t tests conducted, it is evident that there was only one significant difference between the groups in the MMPI scales, on the Sc scale at the $P = .05$ level. There were differences on the EPPS scales on the DEF between the medium and low groups at the $P = .05$ level, on the ORD scale between the High vs. Low and the High vs. Medium groups at the $P = .05$ level, on the AUT scale between the High vs. Low and Medium vs. Low groups, and lastly, on the AFF scale between the High vs. Low group.

In the main, the differences between groups on the ORD scale were quite interesting since they appeared to indicate that the high group had much less need for structuring than either of the other two groups. The other differences between groups are difficult to interpret. They may be nothing more than random occurrences of significance among a predominantly insignificant set of group comparisons.

PHASE II—Sensory Deprivation Studies:—Table III shows the means and standard deviations for the high, medium and low pain endurance groups with respect to number of hours that they voluntarily remained under reduced sensory input conditions.

TABLE III. MEANS AND STANDARD DEVIATIONS OF HOURS DURATION IN CABIN OF PAIN ENDURANCE SELECTED SUBJECTS

	Pain Endurance Selected Subjects					
	High		Medium		Low	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
Voluntary hours stay in cabin	38.2	1.0	35.7	0.4	26.3	.23
Adjusted voluntary	39.9	0.0	36.1	0.2	26.3	.23

It is evident that the subjects remained in the cabin, enduring reduced sensory input, in direct relationship to their ability to endure pain; i.e., the high endurance group remained in the cabin for the longest duration; the medium group stayed in a lesser number of hours, and the low group stayed in the least number of hours. This difference in performance shows up despite the fact that the limit of the duration of stay, unknown to the subjects, was raised from an initial 34 hours to 36 hours and finally, after four subjects were run, to 40 hours for all subjects. When the limit is adjusted to 40 hours, on the basis that some subjects stayed as long as asked and would have stayed more hours if requested, the mean for the high group rises about 2 hours, the mean for the medium group rises by about 20 minutes, but the low group remains the same.

It is clear from the evidence that Petrie's hypothesis that sensitivity to pain is negatively correlated to sensory deprivation sensitivity must be rejected. The relationship between the variables is probably a direct one. Moreover, it is probable that pain endurance ability, not pain sensitivity, is the ability which operated in the present study.

Results of t tests assessing the significance of the mean differences between the pain endurance groups in their durations of voluntary stay in the cabin showed in the adjusted hours in cabin condition that the high group was significantly different from the low group, but the high and medium groups were not different from each other. The same results were evident in the unadjusted scores.

Table IV shows the zero intercorrelations between the predictor variables, the MMPI and EPPS personality scales found significant in the preceding analyses, and hours of voluntary stay under reduced sensory input conditions. It is to be noted that the correlation figures in parentheses in column 15 represent adjusted hours correlated against each of the listed variables. Examination of the figures indicates, in general, that most of them are low.

So far as the pain endurance test intercorrelations are concerned, a reversal is apparent in the relationships between the Iontophoresis—Left Arm Test and the Ischemic Contraction Tests for the pain endurance selected subjects as compared with these same tests for the Total Sample Groups. The coefficients were low in the total groups and one would have expected restricted variance and lower correlations in the more homogeneous groupings of the pain endurance selected subjects.

The relationships between the pain endurance tests and the personality scales yield no significant coefficients.

There is a good relationship, which might be expected, between the post release from cabin rotary pursuit performance and the post telegraph key performance; that is, between gross and fine motor coordination.

Study of the effects of reduced sensory input on the psychophysiological performance of the selected subjects was planned by collection of data on galvanic

TABLE IV. ZERO ORDER INTERCORRELATIONS BETWEEN SIGNIFICANT VARIABLES FOR PAIN ENDURANCE SELECTED SUBJECTS

	No.	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Heat—Right	1	.20	.10	.25	.25	.20	.17	−.03	−.36	.04	.32	−.23	.17	.20	.32 (.40)	.10	−.19
Iontophoresis—1st Admin.	2		.29	.61	.51	−.28	−.25	−.05	−.36	−.09	.16	.35	−.04	.54	.28 (.32)	.09	−.27
Iontophoresis—2nd Admin.	3			.17	.16	−.09	−.09	−.02	−.16	−.03	.10	.11	.03	.50	.06 (.07)	.02	−.42
Ischemic Contraction—Left	4				.59	−.14	−.12	−.13	−.39	−.07	−.38	−.02	.09	.32	.22 (.26)	.09	.20
Ischemic Contraction—Right	5					−.31	−.29	−.08	−.24	−.01	.20	−.04	.09	.13	.05 (.11)	.06	−.00
MMPI—F Scale	6						.85	−.17	−.10	−.10	.24	−.45	.10	−.17	.18 (.16)	.04	−.18
MMPI—Sc Scale	7							−.17	−.04	.08	−.34	−.47	−.05	−.17	.19 (.16)	.04	−.01
EPPS—DEF Scale	8								.12	.26	.24	−.06	−.01	−.06	.01 (.03)	−.02	.55
EPPS—ORD Scale	9									.08	−.47	.06	−.17	−.17	−.20 (−.25)	−.12	.04
EPPS—AUT Scale	10										.43	.07	.46	.07	.10 (.10)	.09	.05
EPPS—AFF Scale	11											−.06	−.11	.70	−.24 (−.16)	.04	−.03
Post Rotary Pursuit Performance	12												.08	.62	−.09 (−.09)	.06	−.23
Post Time Wheel Performance	13													.29	.38 (.02)	.15	.28
Post Telegraph Key Performance	14														.23 (.30)	.10	−.47
Hours in Cabin	15															.21 (.23)	.08
Completion/Non-Completion	16																
Heart Rate—6:00 AM 12:00 Noon—Day 2	17																

TABLE V. MEANS AND STANDARD DEVIATIONS OF LOWEST, AVERAGE AND HIGHEST HEART RATE OF SELECTED SUBJECTS DURING SENSORY DEPRIVATION

	Pain Endurance Selected Subjects					
	High		Medium		Low	
Heart Rate	Mean	S.D.	Mean	S.D.	Mean	S.D.
Lowest Heart Rate	61.3	7.85	59.4	5.22	67.5	12.23
Average Heart Rate	67.6	8.40	69.4	7.71	73.8	12.34
Highest Heart Rate	74.3	10.59	76.9	6.97	80.9	14.81

skin response (GSR), brain activity by electroencephalogram (EEG), heart activity by electrocardiograms (ECG), muscle activity by electromyogram (EMG), and respiration. However, only data on respiration rate and heart activity by EKG were suitable and available for analysis. The respiration data were not discriminating on an intra or inter subject basis and, therefore, no analysis was made of this data. The ECG data in Table V shows lowest average, mean and highest average heart rates for the selected subjects. There were no statistically significant mean differences between the selected groups.

There were interesting relationships between Heart Rate—2nd Day, 6:00 AM—12 Noon and the Iontophoresis Test—1st Administration, the EPPS-DEF SCALE, and Post Telegraph Key Performance. Apparently, high pain endurance was inversely related to heart rate; i.e., heart rate was low when pain endurance was high, and vice versa. A high relationship was evident with respect to EPPS-DEF SCALE. Those who had a high heart rate were likely to be most conforming and deferential, and vice versa. Also, those who had a high heart rate tended to produce low scores on the telegraph key after release from the cabin, and vice versa.

The intercorrelations between the pain tests, selected personality scales of the MMPI and the EPPS, and the criterion, hours of voluntary stay in the cabin were not significant. It is probable that a larger sample would yield higher relationships since there must be high relationships between predictors and criterion to overcome error variance in small samples.

Qualitative Aspects of Sensory Deprivation:—Most subjects who remained under reduced sensory input conditions to the time limit imposed by the experimenters appeared to be in good condition when they came out of the cabin on termination of the experiment. However, a number of those who were unable to endure the experimental conditions to the imposed time limit came out of the experiment with severe headaches and feeling of nausea; some of them vomited. In the interviews conducted on termination of the experiments, most of the subjects who had endured the reduced sensory input conditions best stated that they would not find it objectionable to undergo the experimental conditions again. Conversely, those who did not stay for the full time usually stated that their stays had been oppressive, boring or monotonous and that they would not want to undergo the experiment again.

During the course of the sensory deprivation experiment, subjects who did not stay for the complete time tried to structure their isolation with respect to time and self communication. They gesticulated to themselves, counted on their fingers, played games, recited rhymes, poetry, or hummed songs to themselves, or after an estimated long period of time, some subjects would rub their beard growth to estimate time.

All subjects eventually slept for varying periods of time and usually slept soundly in the period of time between 12 midnight and 6 a.m. After their first nap, most subjects reported that they had lost an accurate notion of time or duration since they began their stay in the cabin. This tended to upset the subjects with least ability to endure the reduced sensory inputs.

Some subjects who were made anxious by the experimental conditions tended to drink water and take food more frequently and in greater amounts than the other subjects.

There were only a few incidents of noteworthy mention which could truly be instances labeled as hallucinations or delusions. Most subjects stated that they had dreamed, but some had difficulty recalling the dream content. Most subjects stated that they knew when they were asleep and when they were awake. In most instances, they felt that it was difficult to maintain a continuous train of thought over a period of time.

DISCUSSION

The central aspect of the present study lay in the search for means to control the effects on man of reduced sensory input. In this respect, it went further than studies which had been reported on the effects of sensory deprivation. The requirement to control this phenomenon was self-evident so far as space travel is concerned.

Discussion of the results of this study on pain, personality and sensory deprivation phenomena divides naturally into consideration of the theory on pain tolerance and on sensory deprivation phenomena and interpretation of its qualitative and quantitative aspects.

Pain Tolerance Concepts:—The measurements in the present study were all suprathreshold. As a by-product, it became clear, also, that there were no well designed and standardized tests of pain tolerance. Some work was necessary and was performed in the present study to produce pain tolerance tests which would be acceptable in terms of such criteria as reproducibility and adequacy of test range. In the present study the Iontophoresis Test for pain tolerance was developed and is considered superior to other tests. In view of the reported data in this study, more work is required to produce other adequate pain tolerance tests. From the evidence in the present study, it is probable that the ability to endure pain is a normally distributed human characteristic.

Sensory Deprivation Concepts:—From the reported literature, it had seemed that distorted perception, as evidenced by rich, easily elicited, hallucinatory-type imagery, was the most important factor to control under reduced sensory input as distinguished from absence of sensory input.[26, 27] There was support for the idea in the literature that disturbances in affect and cognition were intolerable relatively soon to some but that others could endure such conditions for long periods of time.[14, 20] Therefore, it became a matter of finding a sensitivity dimension on which the performance of subjects might be scaled. Then the relationship of pain sensitivity and various personality variables to endurance of reduced sensory input could be determined and a selection procedure formulated.

Survey of the literature on sensory deprivation revealed many experimental procedures that could only yield reports containing hallucinations and imagery.[8, 9, 15, 16, 17] Sherif[24] in his autokinetic experiments, and Asch[1] in his studies of the effects of suggestion on performance have shown that in situations in which subjects possess no sufficient structuring information, subjects will accept suggestion in order to conform and reduce anxiety and produce results consistent with the suggestion.

In the present study, great care was taken to ensure that no suggestion was given to the subjects which could lead them to experience unusual imagery and hallucinations during their stay in the cabin when such events did not occur. On the other hand, nothing was done to prevent the reporting of such events if, in fact, they did occur. It was rather instructive, under the circumstances, to find that there were only a few hallucinatory experiences reported by the subjects. Other effects of reduced sensory input, however, such as restlessness and increased anxiety were observed consistent with reports in the literature.[7, 8, 25]

These findings are interesting in the light of the results obtained by Vernon et al.[26, 27] He had reported that few, if any, hallucinating events occurred in his studies and he had attempted to reconcile his results with those of other studies by reasoning that the complete absence of stimulation in his studies provided different experimental conditions and different results in comparison to the results obtained using reduced stimulation as in other studies. It would appear necessary to confirm many of the reports on hallucination and imagery in well controlled investigations.

Quantitative Aspects of the Study:—In most respects, the Seminary and Montauk Groups were not notably different in their performance on the pain endurance tests. When compared on the personality variables of the MMPI and the EPPS, the Seminary group was significantly different from the Montauk group on a number of variables and this difference seemed consistent with their differences in background. The extent to which these personality differences may have accounted for any variation in subsequent performance is a moot point but, on balance, it seems unlikely that such differences were significant in the present study. Considered with respect to the pain variables, it appears appropriate to consider the Seminary and Montauk sample groups as having been drawn from the same population.

Subsequently, there was a clear and expected difference in performance on the Ischemic Contraction and Iontophoresis Tests showed by the three groups drawn from the sample selected on the basis of their ability to endure pain; the heat test, however, did not yield the differences between groups which had been expected. The performances of the three groups under conditions of reduced sensory input, although lacking statistical significance, was generally consistent with their differences in ability to endure pain. Thus Petrie's hypothesis was not supported and it is likely on the basis of this study that an appropriate hypothesis is that pain endurance and sensory deprivation endurance are directly related. Based on this hypothesis, the relationship of the predictor pain tests with duration of stay in the cabin was in the expected direction. The lack of a statistically significant degree of relationship between the pain variables and the criterion probably was due to the small sample size.

CONCLUSIONS

On the basis of their ability to endure pain, it was possible to categorize and select subjects into those groups most, average, and least able to endure pain.

There was no consistency in, nor were there notable differences between the pain endurance group in performance on most of the personality scales of the Minnesota Multiphasic Personality Inventory (MMPI) and the Edwards Personal Preference Scale (EPPS), with the exception that a significant and systematic difference was found on the ORD scale of the EPPS between the group with the highest ability to endure pain and the other pain endurance groups. This difference suggested an underlying difference in the need of the groups for structuring; this evidence may mean that those who were most able to endure pain and sensory deprivation required the least definition of their environment.

The correlation between the ability to endure pain and the ability to endure reduced sensory input conditions was not statistically significant, although a trend was apparent. A statistically significant difference between the groups probably could be demonstrated with a larger sample of subjects.

Petrie's hypothesis that there is an inverse relationship between the ability to endure pain and the ability to endure reduced sensory input conditions was not supported. There appears to have been a direct, rather than an inverse, relationship between the variables.

Much of the information reported in the sensory deprivation literature on imagery and hallucinatory experiences needs confirmation through well-controlled experimentation.

The evidence of the present study suggests that subjects who were most able to endure pain and reduced sensory input conditions suffered less anxiety with attendant headaches and nausea and remained in good functional condition for a longer period of time than those who were least able to endure pain and reduced sensory input conditions.

The results of this study point strongly to a need for further work to refine predictors and to find new predictors of performances under reduced sensory input. Further study should also be conducted to refine and/or produce a suitable criterion of performance under reduced sensory input.

So far as space travel is concerned, it would appear necessary to explore further the relationship between pain endurance and the ability to endure reduced sensory input conditions and to investigate the effect of training on the ability of all groups to endure reduced sensory input conditions.

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