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THE EFFECTS OF SENSORY DEPRIVATION ON SENSORY, PERCEPTUAL, MOTOR, COGNITIVE, AND PHYSIOLOGICAL FUNCTIONS

by Sidney Weinstein, Milton Richlin, Marvin Weisinger, and Larry Fisher

Prepared by
YESHIVA UNIVERSITY
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Abstract

A series of three experiments was conducted with sensory deprivation as the independent variable and sensory, motor, and cognitive measures as the dependent variables; additionally, various physiological and metabolic variables were measured during the course of isolation. Deprivation took a variety of forms: in two studies the subjects were deprived of tactual sensation alone, and in the third study, they were deprived of visual, auditory, and tactual sensation. The purpose of the latter study was to investigate the effects of sensory deprivation upon the primary levels of functioning within the major modalities. Thus, the major emphasis was on absolute and differential measures of sensitivity, in order to determine whether previously reported impairment of complex functions after sensory deprivation could be attributed to primary losses of sensation or motor function, or physiological or metabolic impairment.

In the first tactual isolation study, the nonpreferred hand was isolated for 24, 48, or 96 hours. Comparison of pre- and postisolation performance was made for the Isolation groups and for a Control group on various visual and tactual thresholds, and tactual discriminations. The results failed to demonstrate the improved sensitivity generally reported in somesthetic isolation studies. In the second study, a replication of a forearm-isolation experiment, we confirmed the earlier finding of improved tactual sensitivity. This result indicates the possible existence of a proximal-distal gradient for the effects of isolation.

A third experiment involved complete deprivation of visual, auditory, and social stimulation, and partial deprivation of somesthetic, kinesthetic, and vestibular stimulation for a scheduled period of 72 hours. Ss were 130 paid male volunteers, aged 18-40, in good physical and mental health, and with at least a high school education. Prior to isolation, Ss were interviewed, and a battery of cognitive, motor, and sensory tests was administered; body weight and hand temperature were also determined. Thirty-four Ss from the same population were randomly selected as Controls, who, after pretesting, resumed their normal activities during the 72-hour period.

The experimental Ss were individually isolated in soundproof cubicles, approximately 4'x9'x8' high, containing a chemical toilet. They lay motionless on a foam-rubber mattress, wearing blindfolds, and ear and hand occluders. Bread, liquid diet, and water were available ad libitum. S was permitted to communicate with E only to terminate isolation which could be requested at any time during the 72-hour period. S was instructed to make no sounds and to lie as motionless as possible. EEG, GSR, breathing, heart rate, and gross bodily activity were recorded for 15 minutes in each hour. S was also monitored continously by E via closed-circuit television and a sensitive parabolic microphone. Following isolation (or the control period), the test battery was readministered and an interview conducted.

Results were as follows:

1. Forty-seven per cent of Ss remained in isolation for 72 hours. There appeared to be a circadian rhythm operating to effect early release, with a maximum number of early releases occurring in late afternoon and early evening, and almost none from midnight to 8:00 A.M.

2. Postisolation interviews revealed that most Ss found the situation uncomfortable and anxiety-provoking. However, few found the experience very disturbing or disorienting. Reports of complex hallucinations were infrequent.

3. A correlation of $-.66$ ($p < .01$) was obtained between GSR and time in isolation, with ambient temperature partialed out, indicating increased activation with time in isolation.

4. An analysis of EEG frequency spectra was completed for 2 Ss. For one S, a significant activation pattern appeared (increased proportion of beta activity and decreased alpha, delta, and theta activity as isolation progressed), while the other S exhibited the reverse pattern (decreased proportion of beta, and increased alpha, delta, and theta).

5. In terms of cognitive functioning, verbal comprehension was unimpaired, while both visual pursuit and space visualization showed a tendency toward decrement in comparison with Controls. Ss who requested early release from isolation significantly changed their estimates of 10-sec. periods from overestimation before isolation, to underestimation after isolation.

6. Hand strength and bilateral finger oscillation rates showed significant decrement on the isolated hand for Ss remaining in isolation for 72 hours. Early-release Ss showed about the same amount of excessive bodily movements as 72-hour Ss during the first six hours in isolation; during the final six hours in isolation, however, those Ss who failed to remain for more than 47 hours were more active than the 72-hour or 48-71 hour early-release Ss.

7. Sensory thresholds (RLs and DLs) were determined for vision, audition, and somesthesis. Thresholds of pain sensitivity and pain tolerance were also obtained. Except for absolute pressure sensitivity on the palm, which showed a decrement for 72-hour Ss, sensory thresholds were unaffected by deprivation.

The data are compared to previous findings in the literature, and their implications for further research in sensory deprivation discussed.

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Table of Contents

Introduction

The relevance of sensory deprivation research to the unusual human environments encountered in e.g., high altitude flight, isolated radar stations, prolonged submarine voyages, and space travel has been frequently pointed out in the literature.

The primary purpose of the present research is the investigation of the sensory, perceptual, and physiological mechanisms affected by sensory deprivation. We have also taken the viewpoint that before ascribing effects to disturbances of higher level functions, one should first test for the integrity of the lower level systems. Thus, for example, a pilot who fails to respond to a warning-light may not have forgotten the meaning of the signal, but, rather, may not have detected its occurrence because of an increase in his difference limen for brightness. Determination of the degree of dependence of complex upon simple behavioral impairment, or upon physiological malfunctioning may enable greater understanding of the role of sensory deprivation in the dissolution of complex forms of behavior.

Our major research purpose has been implemented by studying a broad spectrum of behaviors from the complex (cognitive) to the simple (sensory and motor) along with measures of physiological and metabolic functions (EEG, etc.).

The following table (Table 1) lists the major independent and dependent variables being studied.

Table 1

Variables under Investigation

A. <u>Independent Variables</u>

1. <u>Nature of Sensory Restriction</u>
    a. Sensory deprivation
    b. Perceptual deprivation
    c. Sensory rearrangement (visual)
    d. Sensory rearrangement (nonvisual)
    e. Movement deprivation
    f. Social isolation

2. <u>Modalities</u>
    a. Vision
    b. Somesthesis
    c. Audition
    d. Vestibular, proprioceptive, kinesthetic
    e. All combinations of these

Table 1 (contd.)

3. Durations of Deprivation

   a. 12 hours
   b. 24 hours
   c. 48 hours
   d. 72 hours
   e. Greater than 72 hours

B. Dependent Variables

1. Vision

   a. Absolute threshold for brightness (RL)
   b. Difference threshold for brightness (DL)
   c. Threshold for perception of curvature
   d. Acuity
   e. Threshold for perception of geometric forms
   f. Threshold for perception of verbal material (nonmeaningful)
   g. Threshold for perception of verbal material (meaningful)
   h. Difference limen for hue-saturation (DL)
   i. Simultaneous and successive pattern discriminations
   j. Threshold for perception of slant
   k. Localization of a point in space.

2. Somesthesis

   a. Absolute pressure sensitivity (monofilaments) (RL)
   b. Absolute pressure sensitivity (microesthesiometer) (RL)
   c. Difference threshold for pressure (DL)
   d. Simultaneous and successive tactual discriminations
   e. Thermal discriminations (RL and DL)
   f. Pain sensitivity and tolerance (cold)
   g. Pain sensitivity and tolerance (electrical)
   h. Critical frequency of percussion
   i. Vibration sensitivity

3. Audition

   a. Absolute threshold for loudness (RL)
   b. Difference threshold for loudness (DL)
   c. Difference threshold for pitch (DL)
   d. Discrimination of complex verbal and nonverbal messages under masking

4. Motor Performance

   a. Hand strength
   b. Speed of finger oscillation
   c. Visual-motor tracking
   d. Gross bodily movement

5. Cognitive and Other Complex Functions

   a. Verbal comprehension (written test)
   b. Space visualization (written test)
   c. Visual pursuit (written test)
   d. Spatial orientation
   e. Time estimation
   f. Introspection (structured interview and adjective checklist)

Table 1 (contd.)

6. Physiological Functions
   a. Electroencephalogram (EEG)
   b. Cortical evoked potentials
   c. Basal skin-resistance (GSR)
   d. Pupillography
   e. Heart rate
   f. Breathing rate
   g. Skin temperature
   h. Muscle action potentials
   i. Caloric intake
   j. Water intake
   k. Body weight change
   l. Excreta weight

The major part of this report is devoted to a description of the experiment dealing with the independent variables of 72 hours of total deprivation of movement, auditory, visual, and somesthetic sensation, and social isolation upon various dependent variables. Additionally, studies dealing with limited sensory restriction (hand or forearm), and reliability of sensory tests are reported.

Deprivation of Single Modalities

One of the important questions involved in our overall research design (Table 1) concerns the effects of deprivation of single modalities or combinations of modalities. Two such experiments are reported below: isolation of the hand, and a replication of an experiment by Heron and Morrison (Morrison, 1962; Heron and Morrison, P. C.) on the isolation of the volar surface of the forearm.

The Effects of Isolation of Skin on Tactile Sensitivity, Tactile Discrimination, and Visual Sensitivity

Most studies dealing with the effects of sensory deprivation have predominantly involved vision or audition, rather than the cutaneous senses. A small group of investigators has tried to ascertain the effect of prolonged isolation of skin upon cutaneous sensitivity. In these studies, the only site systematically examined has been the volar surface of the forearm. Aftanas and Zubek (1963a, 1963b, 1964) used plastic cups, and Heron and Morrison (Morrison, 1962; Heron and Morrison, P.C.) used a rectangular structure made of perspex rod and adhesive tape to isolate the skin surface. Aftanas and Zubek (1964) found increased tactual acuity of the isolated skin as measured by tactual fusion and two-point threshold. On the contralateral limb, changes in tactual acuity similar to those produced in the isolated area were present only in the homologous area. However, these changes were much less pronounced than those on the isolated arm. Heron and Morrison, using modified von Frey hairs had previously found results similar to those of Aftanas and Zubek after four days of isolation both for the isolated and for the homologous and nonhomologous contralateral areas.

The purpose of the present study was to determine the somatosensory and perceptual effects of isolating an entire hand, and to note these effects upon the other hand, and upon another modality (vision). The test battery included tests of absolute pressure sensitivity, tactual discrimination, and visual sensitivity. In our experiment, Ss were 48 right-handed males ranging in age from 17 to 35 (M = 22.5).

Method

Isolation was accomplished by encasing the left hand in an opaque, rectangular, plastic box, 22.5 cm. x 9 cm. x 17.5 cm. The box weighed 1120 gms. Inside the box were adjustable finger-bars and a thumb-guard. The finger-bars consisted of two plastic strips lined with foam rubber, between which the fingers were held; the position of the strips could be adjusted along the left side of the box, and the distance between the strips could be increased or decreased. The thumb-guard consisted of two plastic rings which could be attached at any point along the box, with an adjustable distance between them. The box was fitted on S's hand so that the finger-bars pressed firmly against the middle phalanges of the fingers while the thumb-guard was placed between the base of the thumb and the joint. S's hand could not touch the box except at the points of restraint, and the only movement possible was slight flexion of fingers and thumb. The box reached beyond S's wrist, which was wrapped with foam rubber to prevent chafing. Ventilation was accomplished by holes in the box .46 cm. in diameter spaced .5 cm. apart. Over the palm area, fine wire mesh prevented S from stimulating himself through the holes.

Each S was randomly assigned to 24, 48, or 96 hour experimental or control groups. All Ss were tested before and after the pre-established time. The tactual thresholds consisted of pressure sensitivity, two-point discrimination, and point localization, measured on right and left hands. The tactual discriminations consisted of size, roughness, and form discriminations also administered to right and left hands. The visual tests comprised the measurement of brightness threshold obtained through tachistoscopic presentation of a point of light for varying time intervals. Ss wore red X-ray goggles for half an hour to dark-adapt before any testing, and continued to wear them throughout the testing procedure except during the visual test.

There were two orders of administration of the tests. For Order 1 the visual theshold test was administered first, followed by the tactual threshold and then the tactual discrimination tests. For Order 2, the tactual discrimination tests came first, followed by the tactual threshold and then by the visual threshold. The sequence of subtests within each of the tactual tests remained constant in each order. For half the Ss in each order the left hand was always tested first, while for the other half the right hand was tested first. The order of testing, and hand tested first were consistent for each S from pre- to postisolation testing.

Results

A mixed multifactor analysis of variance was performed individually on each of the following measures: tachistoscopic threshold, pressure threshold, two-point discrimination, point localization, size discrimination average error, size discrimination constant error, roughness discrimination average error, roughness discrimination constant error, and form discrimination. For all analyses the three between-group factors were Condition (experimental, control), Order (Order 1, Order 2), and Isolation Time (24, 48, 96 hours). The within-group factors were Pre-Post (pretest, posttest), and Side (right hand, left hand) for all analyses except tachistoscopic threshold, for which there was no "side" factor.

A relevant significant effect was found for point localization for the four-way interaction between Condition, Order, Pre-Post and Side ($\underline{F} = 4.16$, $\underline{p} < .05$). Examination of the pre-post change indicated that whereas the control group as a whole showed a slight decrease in point localization sensitivity, the experimental group demonstrated a large increase in sensitivity, for both right and left hands, when tested under Order 2, and a large decrease in sensitivity when tested under Order 1. Since the time between removal of the deprivation box and eventual point localization testing was longer for Order 1 than for Order 2, the results suggest that point localization sensitivity increases after deprivation but decreases very soon after deprivation is terminated.

The remaining results indicated that for each of the tests there were no significant changes as a function of isolating the skin. Some interesting trends, however, may be noted.

For size discrimination there appeared to be a tendency for the negative constant error to increase with increasing time of deprivation. There also seemed to be a tendency for increased sensitivity of visual brightness thresholds as a function of deprivation time. In general, we must conclude that the results of this experiment were not generally consistent with those found by previous investigators. In the main, we failed to find significant changes in sensitivity after isolation. Since we could not determine whether these results were a function of testing different body parts (hand versus forearm), or to experimental technique, we replicated the Heron & Morrison study, (Morrison, 1962; Heron & Morrison, P.C.) as described below.

Replication of Heron and Morrison Study on Isolation of Forearm

Except for one modification in apparatus (the use of a wooden frame lined with foam rubber rather than a plastic frame) and the use of four additional Ss, the method used in this replication followed that employed by Heron and Morrison.

Subjects and Procedure

Ss were 8 male and 4 female college students ranging in age from 16 to 30 years ($\underline{M} = 20.5$).

The response to punctate pressure stimuli was determined by means of the Semmes-Weinstein esthesiometer, which consists of 20 calibrated nylon monofilaments.* Pressure thresholds were measured for two sites, 2 cm. apart in each of three areas: an experimental area on the volar surface of the forearm, a homologous control area on the contralateral arm, and a nonhomologous (more distal) control area on the contralateral arm. For both the experimental and homologous control areas, the points tested were respectively 4.5 and 6.5 cm. from the elbow, while for the nonhomologous control area the points were respectively 2.0 and 4.0 cm. from the wrist. Starting at various forces above and below the expected threshold, the stimuli were applied in sequence for a total of ten threshold determinations, alternating ascending and descending orders of stimulation (ADAD, etc.). The values of the first filament perceived in each ascending series, and that of the last perceived in each descending series were recorded; the arithmetic mean of the ten values constituted the threshold. The mean of the thresholds for the two points tested in each area constituted its threshold.

For six Ss, the isolated area was on the right, for the other six Ss, it was on the left arm. Within each of these groups the order of testing was counterbalanced, such that for half the Ss the more proximal of the two points in each of the three areas was tested first. The order in which the areas were tested was also counterbalanced such that each of the following three orders was administered to one third of the Ss:
(1) Isolated (I)- Homologous (H)- Nonhomologous (NH); (2) H- NH -I; (3) NH-I-H.

Immediately after pretesting, the isolated area was surrounded by a 4 x 8 cm. rectangle made of 5 mm. wood strips lined with foam rubber. The rectangle was fastened to the skin with three strips of 12 mm. wide surgical tape wrapped loosely around the arm and over the rectangle. A piece of wood across the rectangle prevented the tape from touching the skin. Two gaps, approximately 2 mm. wide, between the strips of tape allowed ample ventilation.

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* A detailed description of the testing procedure and apparatus is presented below, in the Sensory Variables section of the 72-Hour Deprivation Experiment.

After 96 hours, the device was removed and pressure thresholds were measured using the same procedures as in the preisolation test.

Results

The data of the present study and those of the Heron and Morrison study are presented in Table 2. In our study, the regression free gain in each area was analyzed by covariance analyses. The adjusted *F* test was significant ($p < .05$). The individual *t* tests between the three areas showed that the isolated area was significantly more sensitive than each of the control areas ($p < .05$); however, the control areas did not differ significantly from each other.

Having confirmed the results of the Heron & Morrison study (forearm isolation), the most probable explanation of the results of our study of hand isolation is either that the changes after sensory deprivation that occur on the forearm do not occur on distal areas, such as the hand, or that the effects are too small to be detected by the test employed.

Table 2

Changes in Pressure Sensitivity Thresholds After Isolation of the Forearm

	Mean Threshold	
	Present Study (N=12)	Heron & Morrison Study (N=8)
Experimental area		
preisolation	3.81	3.59
postisolation	3.67	3.24
mean change	+.14	+.35
Homologous control area		
preisolation	3.81	3.56
postisolation	3.85	3.42
mean change	-.04	+.14
Nonhomologous control area		
preisolation	3.78	3.38
postisolation	3.84	3.41
mean change	-.06	-.03

Note. Cell entries are in log 0.1 mgm.

Another alternative is that some temporary impairment of the hand (e.g., edema) might have occurred concomitantly to offset any neural or receptor enhancement of function with isolation.

Reliability Tests of Sensory Test Battery

One of the problems anticipated in conducting an extensive postisolation testing session was that the testing itself would reduce or eliminate the effects of isolation. Results for tests later in the sequence might, for this reason, reflect "normal" rather than performance affected by isolation. Varying the testing order would have required inordinate numbers of Ss. Therefore, in order to minimize attenuation of the effects of isolation during the course of postisolation testing, it was decided to test the sensory thresholds first and reduce testing time as much as possible. In order to accomplish this latter goal, cognitive and motor tests were selected which were both of short duration, and acceptable reliability. For the sensory tests, however, it was necessary to initiate a series of reliability studies in order to determine the minimum number of trials required to achieve stable measurements.

The tests examined included those of absolute (RL) and difference (DL) thresholds for brightness, loudness, and pressure sensitivity. Again, to minimize attenuation of deprivation of the involved sense modality, testing was limited to "ascending" series for all threshold measures. Reliability was determined by correlating the mean of the first two, or the first four threshold trials with the mean of the total series of ten ascending trials in each series. A detailed description of the actual testing procedures is presented in the Sensory Variables section of the total deprivation experiment.

The results of the reliability studies are presented in Table 3.

The testing of sensory thresholds for visual, auditory, and pressure sensitivity demonstrated that four trials were highly reliable when compared with ten, in measuring absolute and difference thresholds in ascending series. It was decided, therefore, to employ four trials as a standard procedure in subsequent sensory testing.

Table 3

Reliability of Sensory Tests

Measure	N	Correlation (r) of 10 trials with first 2 trials	first 4 trials
Visual			
RL	32	.96	.99
DL	15	.95	.94
Auditory			
RL	15	.86	.95
DL	15	.82	.92
Pressure			
RL	15	.73	.86
DL	15	.64	.88

Note. All rs are significant at $p < .01$.

Seventy-Two Hour Sensory Deprivation Experiment

The major aspect of the research was to assess the effects of total deprivation (social, motor, visual, auditory, tactual) for 72 hours on various sensory, motor, cognitive, and physiological measures.

The sections which follow present the procedures for preparing S for isolation, pre- and postisolation testing, and finally, description of the effects of isolation on each dependent variable. Table 4 presents an outline of procedures and tests.

Table 4

Outline of Procedures and Test Battery

1. Preisolation Interview
2. Tour of Chambers
3. Adjustment of Tachistoscope
4. Change into Pajamas

Table 4 (contd.)

5. Begin Test Battery (in Test Cubicle)

   a. Verbal Comprehension
   b. Visual Pursuit
   c. Space Visualization
   d. Time Estimation
   e. Adjective Checklist
   f. Hand Strength
   g. Speed of Finger Oscillation
   h. Pain Threshold and Tolerance*

6. Locate and Depilate EEG Electrode Sites+

7. Shampoo and Dry Hair+

8. Attach Electrodes+

   a. EKG
   b. Pneumograph
   c. EEG
   d. GSR

9. Weigh S

10. Blindfold S

11. Resume Test Battery

    a. Pressure RL
    b. Pressure DL

12. Measure Hand Temperature

13. Put on Hand and Arm Occluders

14. Resume Test Battery (Soundproof Test Room)

    a. Auditory RL
    b. Auditory DL
    c. Visual RL
    d. Visual DL

* For Ss who did not have electrodes attached, this test was administered after hand temperature was measured (No. 12 in Table).

\+ Since not all Ss had electrodes attached, procedures requiring electrode application were not always applicable.

Table 4 (contd.)

15. Place S in Isolation Chamber
16. Connect S's Cables to Panel Cable+
17. Isolation Period (scheduled for 72 hours)
18. E enters Isolation Chamber at end of period or if S leaves early
19. Disconnect Cables+
20. Lead S to Soundproof Test Room
21. Remove Ear Occluders
22. Put on Earphones
23. Begin Postisolation Test Battery

    a. Audio RL
    b. Audio DL

24. S Removes Blindfold
25. Resume Test Battery

    a. Visual RL
    b. Visual DL

26. Lead S to Test Cubicle
27. Remove Hand and Arm Occluders
28. Blindfold S
29. Remove GSR Electrodes+
30. Resume Test Battery

    a. Pressure RL
    b. Pressure DL

31. Measure Hand Temperature
32. Remove Blindfold
33. Weigh S

+Since not all Ss had electrodes attached, procedures requiring electrode application were not always applicable.

Table 4 (contd.)

34. Resume Test Battery

    a. Hand Strength
    b. Speed of Finger Oscillation
    c. Pain Threshold and Tolerance
    d. Time Estimation
    e. Verbal Comprehension
    f. Visual Pursuit
    g. Space Visualization
    h. Adjective Checklist

35. Postinterview

36. Remove Electrodes[+]

Subjects

Ss for this experiment were recruited mainly from colleges in the New York metropolitan area. The sample was restricted to males from 18 through 40 (range 18-34, M = 21). Ten percent of the Ss had high school education, 78 per cent completed some college, 10 per cent were college graduates, and 2 per cent had graduate training. Ss were chosen only if they met all the following criteria: normal intelligence, vision, and hearing, good general health, no known severe emotional problems or neurological impairment, and no history of any other serious illnesses. Control Ss who were drawn from the same population as the experimental Ss were tested concurrently. All Ss came to the laboratory prepared to be control or experimental Ss, were randomly selected for either condition, and informed of the decision after preisolation testing had been completed. All Ss were reimbursed according to a pre-established schedule of fees.*

A total of 130 Ss began the test battery. Of these, 36 were assigned to the Control Condition and 94 to the Isolation Condition. The data analyses reported below are based, however, on a maximum possible total of 24 Control and 44

[+]Since not all Ss had electrodes attached, procedures requiring electrode application were not always applicable.

*The rate for an experimental S, who remained for the full 72-hour isolation period was $70. For control Ss the rate was $15 for the two test sessions.

Isolation Ss:*

Initial Interview

E interviewed S (tape recorded) obtaining information concerning: visual and auditory acuity, smoking habits, previous major illnesses, current medical problems, S's knowledge about sensory deprivation, and expectations concerning the experiment. E then described the requirements and conditions of the experiment. The requirements were: while in the chamber there be only necessary movements, no talking or other production of sounds, and S must remain lying down, except for eating or use of the toilet.

S was then shown the isolation chamber in which he would be staying, and the area from which E would monitor him (by TV and microphone). He was told that if he wished to leave isolation before the scheduled 72 hours, he could do so by throwing the switch in the room, which so informs the monitor. This procedure eliminated the last remaining necessity for speech during isolation. He was further told that once the switch was thrown, the decision was irrevocable and that he would be taken out within 30 minutes. S was asked at this time whether he wished to participate in the experiment before testing began.

Attachment of Occluders

After S changed into pajamas, the test battery was administered and the preparations for isolation were continued. Prior to beginning isolation S had special occluders placed in position by E. S, prepared for isolation, is shown in Fig. 1.

There were several types of sensory occluders used. For somesthetic isolation, a specially designed cuff was placed upon S's nonpreferred hand. This cuff consisted

*A total of 21 Ss (4 Controls and 17 Experimentals) were eliminated from all analyses because they did not meet the criteria for acceptance in the sample: 13 Ss had a chronic medical condition, 3 Ss had a current illness, and 5 Ss had ingested drugs less than 72 hours before testing. Two additional Experimental Ss were eliminated because of procedural difficulties in preisolation testing. The remaining 107 Ss were used as the screening sample described below. The posttests of 39 Ss (8 Control and 31 Experimental) were eliminated entirely. Five Control Ss failed to return for testing, 2 suffered excessive fatigue or injury during the intervening period, and 1 refused to cooperate. Twenty-seven experimental Ss broke isolation (by removing occluders, or exercising, or making noise), 1 withdrew prior to entering isolation, 1 was removed from isolation at his parent's request and 2 were eliminated due to procedural difficulties. Further, S's test data for an individual test were excluded from the analysis if his pretest score was more than 1.65 standard deviations from the mean pretest score of the screening sample (in the direction of poorer performance). A minimum of 5% of the poorest performers were eliminated from each test. Additional attrition on individual tests occurred when S gave more than two false positive responses during a threshold test, or from occasional equipment malfunctioning.

Fig. 1. S in Isolation Chamber

of an aluminum frame fitted over the hand and strapped to the wrist with a watchband. The fingers were clamped between two bars of aluminum padded with foam, and the thumb was strapped to the side of the frame, keeping the hand open and the area between the wrist and the first joint of the fingers suspended. A mitten made of fine nylon mesh was placed over the aluminum frame, permitting ventilation, but preventing S from stimulating his hand. A plastic cylinder with ventilation holes was suspended over the forearm, supported at the distal end by the hand-isolating device and at the proximal end by foam rubber.

A light cardboard tube with ventilation holes and foam rubber lining around the edges (custom-made for each S) was fitted over the preferred hand and forearm. It permitted use of the preferred hand (for eating, etc.) while reducing movement and tactile stimulation.

For auditory deprivation, S wore ear occluders (Straightaway Ear Protectors Model 10A) which attenuated sound approximately 30 db.

For visual deprivation, black light-shields (manufactured by Flents Product Co.) were taped to S's face. Small light leaks were sealed with absorbent cotton and black velvet, and the shields taped again. This occluding device allowed Ss to open their eyes without seeing light.*

Isolation and Testing Chambers

The isolation and testing chambers were built and installed by Industrial Acoustics Corporation. (A floor plan is shown in Fig. 2). They consisted of a suite of five sound-attenuated and electrostatically shielded rooms. The double-walled testing room was centrally located, with two single-walled isolation chambers on either side. Sound attenuation was 70 db for the test chamber and 40 db for the isolation rooms. Audio communication with each of these chambers was possible from the monitoring area in the rear of the large outer room. Monitoring of the activity within the isolation chambers was accomplished by means of a microphone in a

*The isolation chamber was continuously illuminated in order to view S on closed-circuit TV and through the one-way window.

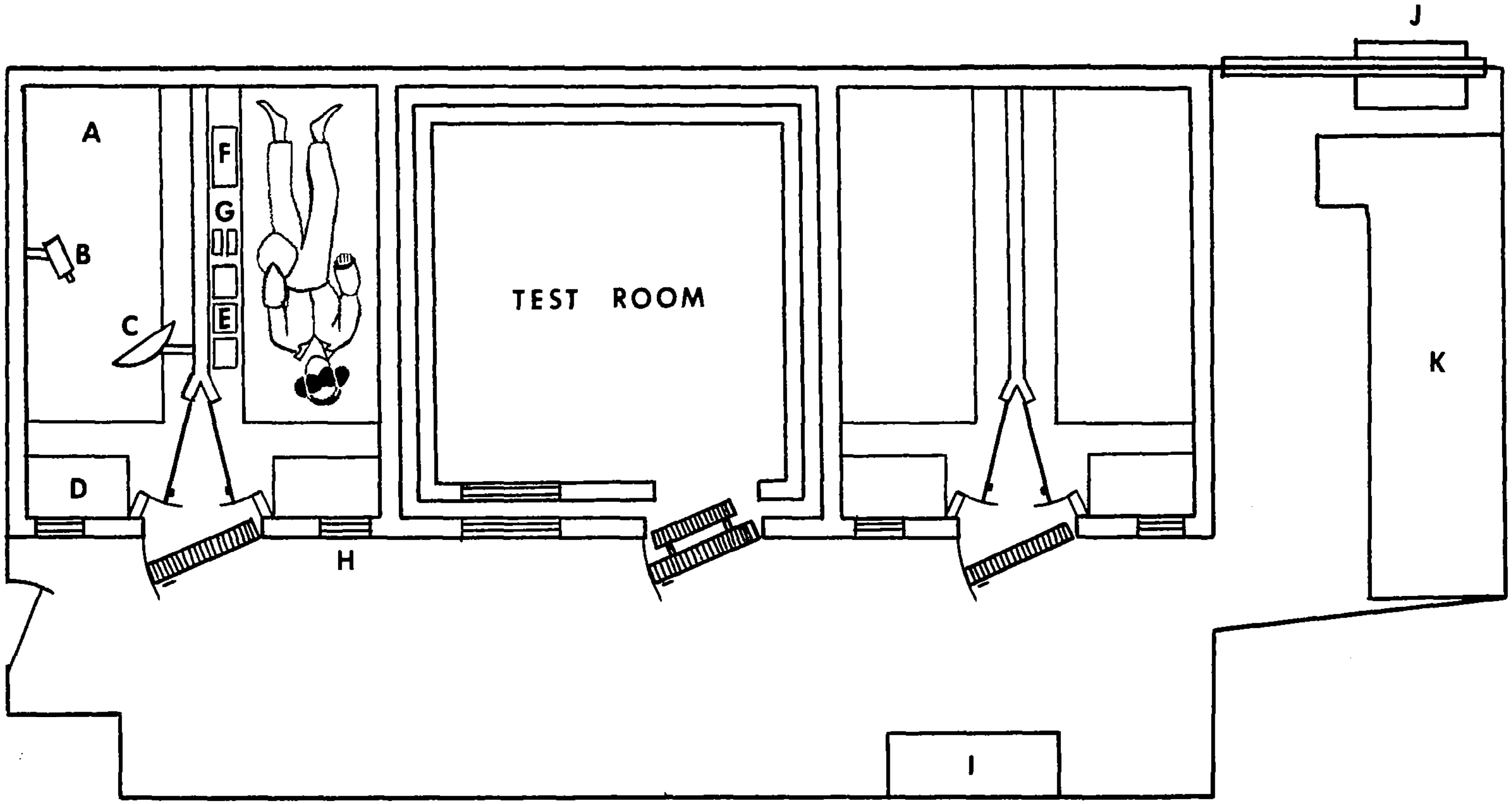

Fig. 2

Floor Plan of Isolation Study: Test and Isolation Chambers, Monitoring, Stimulating, and Recording Areas

<u>Note</u>: *All four isolation areas contained the equipment and material listed below.*

A. Foam rubber mattress
B. TV Camera
C. Microphone in parabolic reflector
D. Chemical toilet
E. Container of water
F. Loaves of bread
G. Cans of liquid diet
H. One-way window
I. Experimenter monitoring area
J. Air conditioners
K. Stimulating and recording area

parabolic reflector, a closed-circuit TV camera, and a one-way viewing window (Figs. 1 and 2).

Within each chamber was a specially-constructed foam rubber mattress upon which S reclined during isolation, a chemical toilet, cans of liquid food, loaves of bread, jars of water, a can opener, waste basket, and premoistened cleansing tissues. Cables connected the electrodes from S to a patch panel from which the signals were carried to recording and monitoring equipment in the general monitoring area.

S was taken to the isolation chamber, where he was shown the food, the use of the can opener, how to drink water through the plastic tubes, the use of the toilet, and the cleansing tissues. After the occluders were attached, S reclined on the mattress, and was reminded that he was to lie quietly until the end of the 72-hour period, at which time he would be taken from isolation. He was reminded that when the isolation period was over, he would be taken immediately to the test room for auditory testing, and was further instructed that he had to remember the procedures for those tests, since the instructions would not be repeated at that time. The purpose of the latter procedure was not to attenuate the effects of auditory deprivation during testing.

Monitoring During Isolation

After E had closed the door to the isolation chamber he started a digital clock, specific to each S, in the monitoring area (Fig. 2) which indicated total time spent in isolation. S was continuously monitored throughout the isolation period via closed-circuit TV, earphones, and occasionally via the one-way window. Special activities such as eating, drinking, going to toilet, or excessive activity were recorded on specially designed data sheets. Physiological activity was recorded for 15 minutes in each hour for each S wearing electrodes during the entire 72-hour isolation period.

Results and Discussion

In the following sections, the procedures and results of the experiment are described and discussed for each of the dependent variables. There are five major areas:

1. Reactions to Isolation: Early release from isolation; postisolation interview.

2. Physiological variables: EEG; GSR; hand temperature; body weight; food and water consumption; weight of excreta.

3. Cognitive variables: Verbal comprehension; visual pursuit; space visualization; time estimation; adjective checklist.

4. Motor variables: Hand strength; speed of finger oscillation; bodily movement.

5. Sensory variables: Somesthesis: absolute and difference thresholds for pressure; audition: absolute and difference thresholds for loudness; vision: absolute and difference thresholds for brightness; pain: sensitivity and tolerance thresholds.

1. Reactions to Isolation

In the subsequent sections of this report the more technical aspects of the research are dealt with. First, however, it may be of interest to describe some of the qualitative aspects of our findings, particularly the rate of early release and the reactions to isolation reported in the postisolation interview.

Early Release from Isolation

A general finding in sensory deprivation research is that a certain percentage of the experimental Ss fail to remain in the isolation chamber for the scheduled time period. As in other studies, our Ss were told that they could leave isolation at any time. It was emphasized that once they transmitted this decision, it was irrevocable. Further, early release was discouraged by informing S of a sliding scale of payments, such that the rate of compensation was proportionally greater with succeeding days in isolation.

The overall rate of early release was 53%, a somewhat higher figure than that reported by Vernon, et al. (1961): 32%, Heron, et al. (1961): 31%, or Zubek, et al. (1962): 32%, but similar to the findings of Murphy, et al. (1962): 52%. As will be shown in the interviews, the discomfort experienced in the present experimental situation was a major factor in some of the early releases. We were interested to see whether any factors were related to early release. In Fig. 3 the number of Ss leaving during given time periods is plotted against both isolation time and calendar time. That is, in the upper graph the abscissa represents the number of hours S was in isolation. In the lower graph the abscissa is actual calendar time; this may represent a differing number of hours in isolation for the Ss, since they did not all enter isolation at the same hour of the day.

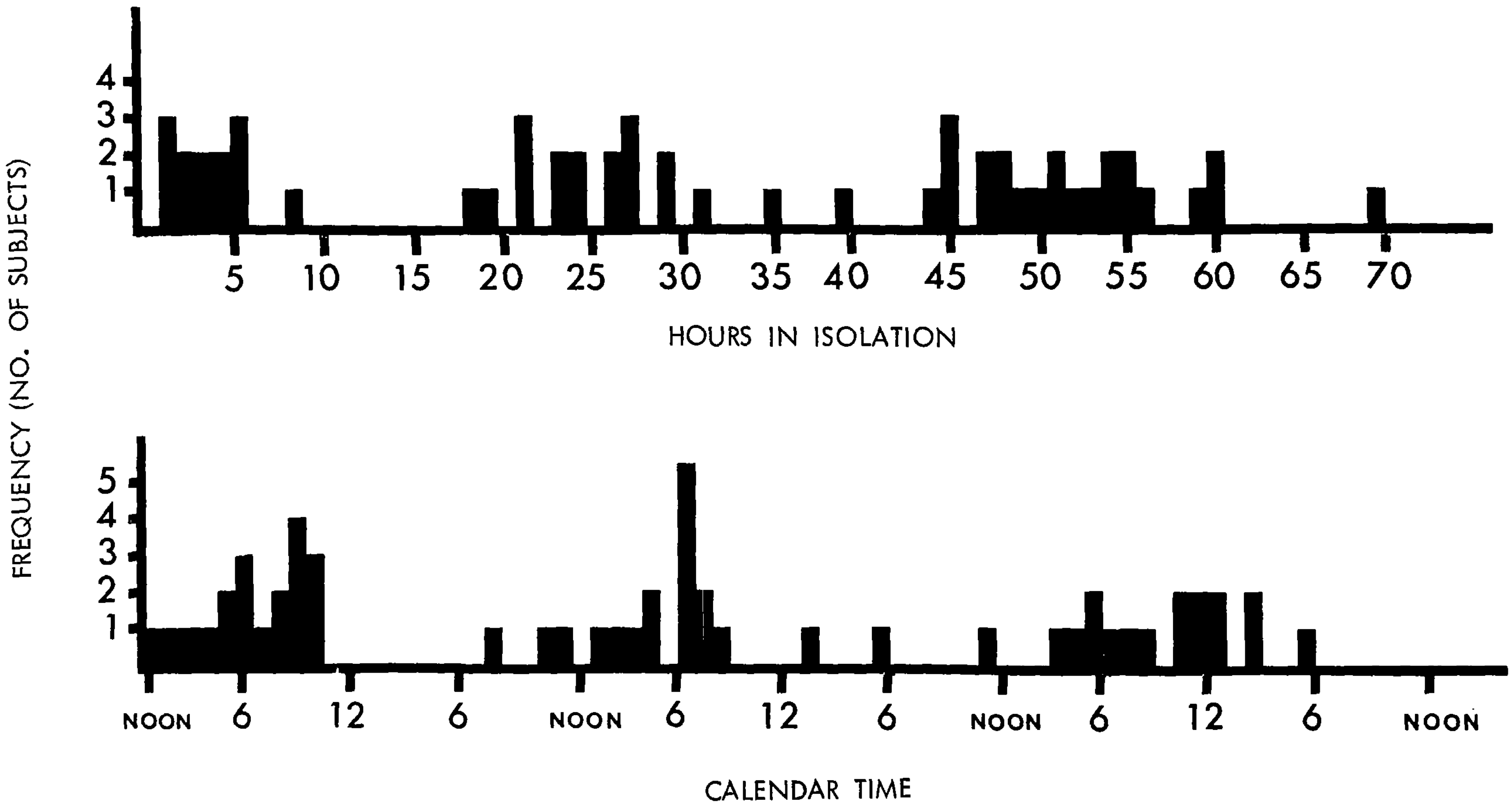

Fig. 3. Distribution of Early Release Ss as a Function of Isolation Time and Calendar Time.

The time that Ss chose to leave isolation appears to follow a circadian rhythm which is somewhat more obvious for the calendar time plot than it is for the isolation time plot. The maximum number of early releases occurred during the early evening hours, and a minimum number during the early morning hours. This is consistent with two factors: S's maintenance of a normal sleeping rhythm while in the isolation chamber despite the lack of any external indication of time, and secondly, as the number of hours since sleep increased, early release was more likely. These conclusions are supported and amplified by data from the interviews and from recorded bodily movement which are presented later.

Postisolation Interview.

After the completion of postisolation testing, a standardized interview was conducted with the isolation Ss. This interview was identical to the one used by Myers (Personal Communication).

The entire interview was tape-recorded. A content analysis of these tapes was then performed and response categories established. Each interview was then "scored" utilizing these categories, and response frequencies analyzed by means of an IBM sorter.* These results are summarized below for a sample of 51 experimental Ss. In this group, 27 Ss completed the 72-hour period of isolation, while 24 remained for briefer periods. The durations of isolation in these early-release Ss ranged from 3-60 hours (M = 35.7 hrs.).

General anxiety. About 80% of the 51 Ss said that they experienced some anxiety while in isolation. Of these, about 25% reported that this feeling occurred only once or twice, while another 25% reported that the feeling was continuous. In addition, about 40% of the Ss reported that they were bothered by frightening thoughts or ideas. Of the 27 Ss in this sample who remained in isolation for the full 72 hours, 74% said that they wanted to leave isolation at some time, and 58% of the 24 Ss who did leave early also reported that they wished to leave before they actually did so. Furthermore, about 40% of all Ss wondered at some time whether anyone was there to help them if they had to leave isolation.

*Provided, free of charge, by the computer facility of Farleigh Dickenson U., Teaneck, N. J.

It seems fairly clear that the experience of isolation provoked anxiety in a significant number of Ss.

Subjects' complaints. The postisolation interview elicited a multitude of complaints concerning various aspects of the equipment, procedures, etc. to which S was subjected. The following section is concerned with complaints directed to these specific areas.

Confined space. There was little evidence that prolonged confinement in the restricted isolation space induced feelings of claustrophobia; only 12% reported feeling that the room or space was closing in on them, and only 8% reported feelings of being buried. Thirty-one per cent of the Ss reported feelings of suffocation. Eighty per cent of the Ss said they felt the need for some kind of exercise, and most would have preferred to move freely about the room. However, there was no evidence that this need had any effect on S's decision to leave early. It is interesting that Ss who remained for the full 72 hours reported more frequently the need for exercise and desire to move about the room than did Ss who actually left isolation.

Food and water. Half the Ss objected to the food offered; 60% would have preferred some other kind of food, and 38% reported experiencing specific food cravings (mostly for meat, particularly steak or hamburgers). Most Ss (80%) said the water was acceptable.

Experimental equipment. Upon being asked whether any of the experimental equipment disturbed them, 50 of 51 Ss replied affirmatively. The ear occluders were the most uncomfortable for 44%, cuffs for 14% and blindfolds for 12%. Of the 10 Ss who wore electrodes, 8 found them most uncomfortable.

Monitoring. Sixty-nine per cent said they knew they were being watched but didn't mind, and 31% had no awareness of being watched. Of those who had the awareness, most were indifferent to it, 4% felt reassured, and 6% had unpleasant feelings about being watched.

Summary. Most Ss found the specific physical arrangements of this experiment uncomfortable. The diet was monotonous, the room cramped, the restricting equipment uncomfortable. These factors, however, did not differentially influence those Ss who remained or failed to remain in isolation.

Sleep and dreaming. Most Ss (76%) tried to sleep as much as they could, in order to pass the time more quickly. Reported dreams covered a wide variety of topics, including past events, food, the experiment, etc. Only 14% of the Ss reported that they did not dream; of those who dreamed, 60% were able to describe one or more of their dreams. Most Ss reported that their dreams were generally pleasant, only 12% reporting mostly unpleasant dreams. In addition, 55% of the dreamers reported that they dreamed in color. Over half of the Ss (52%) said that their dreams while in isolation differed from their usual dreams; the distinction most often given was that their dreams in isolation were more jumbled and fragmented than normal.

Most Ss had no difficulty orienting themselves within the room when they woke up. A total of 6 Ss (5 of the 72-hour group) reported spatial confusion when they awoke.

Intellectual processes. Forty-eight per cent of the Ss reported some difficulty in thinking while in isolation. Most of these Ss reported that their thoughts were jumbled, i.e., they could not clearly organize their thoughts, and that this lack of clarity was beyond their control. Ten per cent reported that the effort involved in thinking clearly was too great, and that they simply gave it up.

Forty-two per cent reported that their thoughts were mostly conceptual, while 30% principally employed visual imagery. Seventy-two per cent said that they tried to work out personal and intellectual problems. Half of those who attempted this said they experienced difficulty.

Eighty-four per cent of Ss daydreamed; 54% said they spent some time in fantasy, or imagining themselves in particular situations. Only 8% of these Ss reported that their daydreams or fantasies were mostly unpleasant. Half the Ss reported that they thought a lot about girls, but only 34% said they thought a lot about sex. A little less than half (46%) of Ss had angry thoughts, and only 14% reported that they had any unusual or strange thoughts.

Subjective time estimation. Ninety per cent of Ss had difficulty keeping track of time, and of these, 85% reported that they were disturbed by this fact. For most Ss, time seemed to go slowly, particularly when they were awake. Seventy per cent reported that they had trouble making time pass. Throughout the postisolation interviews there was frequent reference to the fact that there was preoccupation with time. Ss reported that they tried many devices to keep track of the hours: trying to estimate beard growth, taking a piece of bread out of its wrapper and allowing it to go stale, counting pulse and respiration, counting eating periods, trips to the toilet, etc. In most cases these efforts were reported to be unsuccessful.

Orientation in space. Only 10% of the Ss reported that they wondered where they were, or felt they were somewhere else, and most (95%) had no difficulty finding their way around the room.

Bodily discomfort. Eighty-two per cent of the Ss reported some degree of bodily discomfort. The most frequent specific complaint was backache (34%); headache (12%), eyeache (8%) and earache (4%) followed in order. In addition, 54% of the Ss complained of general bodily discomfort from the restrictions imposed on their position by the equipment. Twenty per cent of the Ss complained of nausea, diarrhea, or constipation.

General response to isolation. Thirty-one per cent of the Ss said they were bothered by the darkness, boredom, or both. Only 20% reported that they felt in danger at any time. Twenty-eight per cent reported that at some point they thought someone else was in the room with them; the most frequently reported response was that S thought E had opened the door, and was standing in the doorway or had come into the room. Eight per cent reported feeling that someone was trying to influence them; 34% thought that Es were trying to trick them in some way they had not been informed about, e.g., keeping S in isolation longer than 72 hours to see if he could "take it," or varying the temperature of the room. A few Ss discovered one of the switches in the mattress which recorded movement and, not realizing what it was, became suspicious. Fifty-eight per cent felt some annoyance at finding themselves in the isolation situation; 18% were annoyed at E, 28% at themselves, and 12% at both, while 40% felt no annoyance.

Only three Ss experienced bodily sensations of rising, falling, or both, and these three were among those who left isolation very early. Two Ss of the 72-hour group felt they were rocking or tilting out of position.

Reported Visual Sensation (RVS).* RVSs were reported by 41% of Ss, a percentage in line with that reported by Zuckerman and Cohen (1964) in their review of the literature on isolation studies.

It has been found that visual sensations form a Guttman scale of intensity (Murphy, Myers & Smith, 1963). That is, Ss who report complex visual imagery also report the simpler forms of imagery. In the present study, there is some indication that this scalability of RVS holds.

The RVSs obtained in the present study may be classified as follows: 30% reported lights and flashes; of these Ss, 43% additionally reported geometric shapes; 7% of the latter group also reported such complex sensations as wall paper patterns, objects, people, etc.

Reported Auditory Sensations (RAS).* RASs were also described by the Ss. However, in the absence of total sound attenuation the general findings on auditory hallucinations are not so clearcut as are those for visual hallucinations. The S's own internal processes create some sound, even if all external sources are eliminated. It has previously been found (Zuckerman & Cohen, 1964; Vernon, et al., 1961) and confirmed in the present study, that Ss sometimes interpreted these sounds as coming from objectively improbable sources, such as falling rain, the hum of heavy machinery such as a dynamo, or to airplanes passing close overhead. Because of the questionable validity of attempting to classify these low-level, rushing, muted-roaring, or high-pitched whining sounds in terms of reality, they are best regarded as nonhallucinatory. However, if S reported hearing meaningful sounds which clearly could not have been present in the isolation chamber, these were classified as RASs. Only 4 Ss reported sensations which could be clearly classified as auditory hallucinations.

One S had a vivid dream, which seemed real on waking, that E had spoken to him through the earphones, telling him the experiment was over, and that he could remove his equipment. It took the S some time to decide that the voice had not been real. Another S heard what he described as a "hollow" voice speaking to him from within the room. S investigated, and convinced himself that the voice could not have

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*The sample for this section of the analysis is augmented by 22 Ss who, because they broke the rules of isolation (by removing blindfolds, etc.) were not tested but were interviewed.

been real. This S developed a severe abdominal pain which caused him to leave isolation. The pain, which he described as "different from any I had ever had," subsided immediately upon his release from isolation. A third S reported that he heard a "pure tone" being transmitted through the "earphones." A fourth S reported he heard E enter the isolation chamber about every three hours to check on the food supply, etc. He "felt" the mattress move when this happened.

Multimodal experiences. In addition to hallucinations limited to one sense modality, a number of Ss experienced complex sensory hallucinations involving several sense modalities. A summary of these experiences is given below.

S 6 felt several times that his body was getting heavy and numb.

S 11 at one point had the strange feeling that he had two heads, the second clearly separated from first.

When S 14 thought isolation time had ended he believed there were one or two people in the room with him, ready to take off his equipment. He felt the wall, found no one was there. The room felt larger when this occurred.

S 22 had a complex sensation that he was talking to his friend in the room next door via ESP.

S 29 smelled persistent, delicious food odors, and thought E was testing his reactions.

S 37 had one experience of being out of his body, above it, where he could watch it lying on the bed. He also had a brief sensation that he and the room were rising and floating in space.

S 39 left isolation before 72 hours because he had the following vivid fantasy: No one was monitoring because he was in Chicago, and someone had driven up to the hospital, jumped off the roof, and committed suicide. All the doctors, nurses, etc. including the monitors, had run out to see the man jump off the roof, so S was alone. He shouted to be let out, and was.

S 52 had the brief sensation of strangling on cords at the very beginning of isolation.

S 53 thought door was opened several times, and that E was watching him.

S 67 had a very vivid dream, which seemed real on awaking, that someone was talking to him, telling him that he could come out. He was disoriented, and took some time to reorient.

S 79 had a very vivid dream, which he couldn't distinguish from reality until he removed blindfolds. He identified the present situation with POW camp, and brainwashing. He believed that the situation was highly threatening, a conspiracy on the part of the Es. He tried to sit it out, found finally that he couldn't, and removed blindfold. He reported that he felt sort of foolish when he realized where he was.

S 83 had what he described as "paranoid feelings" related to what would happen if the place burned down. He believed there were people pushing their faces against the window of the room watching him.

S 84 felt that someone was in the room with him, pressing down on the mattress. He reached for the person several times, but couldn't find him.

S 93 had a strong feeling, which caused him to leave isolation, that the walls of the room were coming closer to him. Also, he felt that there was pressure on his face, and that he was in danger of suffocation.

S 113 thought that someone had come into the room, but when he checked with his hands, no one was there.

S 114 had a vivid sensation at one time that a lot of people, 5 or 6, were in the room with him. People were like the "Beverly Hillbillies." He knew the sensation was not reality. He was not asleep at the time; said sensation "burst on me like an explosion."

S 121 felt that someone came into the room, that things were displaced (mattress moved, etc.). He said this happened every 2 or 3 hours. S was convinced during interview that this had actually happened, that Es were checking on him, making sure he had enough food and water, etc.

S 128 thought he was being kept in the chamber more than 72 hours, that occasionally people were trying to help him escape.

A check of the literature on sensory deprivation indicates infrequent reporting of experiences directed exclusively toward the isolation environment by investigators using laboratory methods (e.g., Cohen, et al., 1961). These experiences bear a striking similarity to those reported by Steinkamp & Hauty (1961). They reported that all their Ss, confined in a simulated space capsule for 30 hours, and required to perform vigilance tasks, experienced complex sensations which had a detrimental effect on performance. Their Ss, like the present ones, were aware that the perceptual distortions which they experienced were not real.

It is not possible to determine which aspects of the present experimental conditions distinguish them from those of other experiments. However, one possibility is that the present conditions led to increased vigilance on the part of some Ss. Our Ss were quite uncomfortable. They wore confining equipment, and were not allowed to move around the small area of the room. Some Ss responded to this situation with increasing anxiety, which presumably produces increased arousal. These Ss were, perhaps, increasingly vigilant in regard to the environment around them. It should be noted that all the complex sensory experiences were related to the sensory deprivation situation per se, i.e., fear of being left alone, feelings that the E was watching him (or watching over him), feelings of danger from strangulation, suffocation, etc.

Olfactory experiences. Seventy per cent of the Ss reported noticing smells from the chemical toilet, the bread and liquid diet, the cleansing tissues, and from their own body. Many of these Ss reported that they found these odors quite pleasant. Fourteen per cent of the Ss reported smelling things which were not present. Two Ss said they smelled something burning (one said it smelled like burned coffee), one smelled oranges, two reported delicious food odors (broiled steak, beer), one S reported a bad but unidentifiable odor, and one thought he was being given sleeping gas until he identified the odor as coming from the pillow case.

Adaptation to experimental environment. Sixty per cent of the Ss said they noticed no difference in feelings, thoughts, sensation etc. from the beginning of isolation until it ended. Only 12% said they did not attempt to stimulate themselves in some way, such as wiggling their fingers or tapping their toes. Twenty per cent reported an increase in tension, anxiety, or discomfort as time went on, and 12% reported a decrease. Two Ss reported increasing feelings of unreality, one had feelings of heightened sensation, e.g., feel of the bread and the sheets, taste of the water, etc. Another S had abnormal sensations in his right arm. The fourth S became dizzy toward the end of his isolation time whenever he sat or stood up.

Postisolation effects. Almost all Ss reported some dizziness and weakness on first emerging from isolation, and the longer S had been in the chamber the more likely he was to report this. Fifty-two per cent reported that the environment looked, sounded, and felt normal when they emerged. Of the 12 Ss (24%) who reported visual disturbance, 7 said their vision was blurred, 3 that their vision was distorted, and 2 reported unusual vividness of visual sensations. Of the three Ss (6%) who reported auditory disturbance, two said that they had a persistent humming or ringing in their ears, and one that everything sounded "unusual." Further, one S said he felt as if the floor were made of foam rubber. Three Ss reported disturbance in all modalities.

Subjects' feelings about experiment. Forty per cent of the Ss said they would be willing to serve as Ss again, but none was willing to return immediately to isolation.

Most Ss were relatively uninformed about sensory deprivation research, and 50% of the Ss expected the experimental arrangements to be more comfortable than they actually were. Half the Ss expected to be able to "take" the situation, 18% expected it to be pleasant, and 16% expected it to be unpleasant; 68% said they had reacted differently than they had expected, and in most cases this was because the situation was far more uncomfortable than they had anticipated.

When asked which sense modality they would have preferred not to be restricted, 62% said vision, 22% audition, and 6% touch. The usual reason was it would help to pass the time.

S's reasons for leaving isolation early. It is interesting to note that the reasons given for leaving isolation changed as a function of the number of hours of isolation. Table 5 presents the distribution of reasons for leaving given by the 24 Ss who did not remain for the scheduled 72 hours. For the four Ss who left within the first nine hours of isolation the reasons given were:

Table 5

Reason for Leaving Isolation Early

		Percentage[a] of Group Giving Reason			
Range of Hours in Isolation	N	Boredom, Restless, Claustrophobia	Discomfort	Lost Track of Time	Other
3-9	4	100	25	0	0
21-32	9[b]	16	100	16	16
48-60	11[c]	10	60	80	20
Total $M = 37.5$	24	30	65	45	15

a. 100% is exceeded in each row since some Ss used more than one reason.
b. Percentages based on N = 6 (3 Ss gave no reason for leaving).
c. Percentage based on N = 10 (1 S gave no reason for leaving).

boredom, restlessness and claustrophobia. As was shown earlier (Fig. 3), a "sleep-gap" follows during which no S left isolation. After 21 hours, and lasting through 32 hours, Ss again left isolation. The six Ss who tolerated between 21 and 32 hours of isolation left mainly because of the discomfort. Ss who left after 48 hours quite consistently complained about their inability to keep track of time.

A number of typical responses are quoted below. Parenthetic figures are hours spent in isolation.

(3 hrs.): Strong feeling that "walls were closing in" on him. Felt "pressure on face," "danger of suffocating."

(5 hrs.): "Couldn't keep mind on anything," "had wanted to use this period of the experiment to review my life, found I couldn't, became annoyed, and came out."

(9 hrs.): "Felt very restless, couldn't relax; I felt I was defeating the purpose of the experiment."

(21 hrs.): "Felt hot, uncomfortable, cramped; equipment was uncomfortable, blindfold especially irritating."

(29 hrs.): Left isolation because of, "physical discomfort" and because he, "could not achieve detachment from the situation."

(32 hrs.): "Became very uncomfortable," "found electrodes painful," "muscles ached," "decided it wasn't worth it."

(48 hrs.): "Lost track of time," "didn't know how long I had been in, therefore, how much longer I had to go"; became "very uncomfortable and irritated at the situation," so he left.

(51 hrs.): "Couldn't stand it any more," " lost track of time, had no idea how long I was in," " thought door would open any minute and 72 hours would be up."

(55 hrs.): Left isolation because, "the electrodes were very uncomfortable," "didn't know how long I had been in, but thought it was about 24 hours"; couldn't finish because, "the length of time ahead was too great to stand the discomfort."

Summary. The data from the postisolation interview indicate that the experience is stressful, but realistically so. That is, the Ss are uncomfortable, bored and would like to move about. There are indications of some anxiety, but not panic. Nevertheless, a considerable number of individuals would not, or could not, remain in isolation for the scheduled period so that the experience may be considered an individual "test" of a response to stress.

2. Physiological Variables

The importance of studying some of the basic physiological responses of the individual during isolation has been mentioned earlier. First, these responses are of interest in broadening our overall knowledge of what is happening to the individual during sensory deprivation. Second, the physiological responses may be used to predict the sensory, perceptual, cognitive and motor performance of Ss who have undergone varying types of isolation.

While other investigators have studied some of these variables, they have continuously recorded them either for short periods of isolation, for longer periods with relatively infrequent sampling, or at the conclusion of isolation. The present study represents one of the first attempts to record physiological variables during the entire period of long-term isolation. Employing this method, the time course of any physiological changes may be more precisely examined.

In the following sections, procedures and data dealing with basal skin-resistance (GSR), electroencephalography (EEG), hand temperature and metabolic variables (food and water consumption, and body and excretion weights) are considered.

Basal skin-resistance (GSR)

Electrode attachment. The middle and ring fingers of the nondominant hand were first cleaned with alcohol. Silver discs were placed in hard rubber wells which were filled with Sanborn Redux paste, and the electrodes attached to the skin with Eastman 910 cement. Placement was such that the whorl of the fingerprints and the lumen of the electrode-well were concentric. The electrode and wires were then taped to the finger. The wires, which led to the cables in the cubicle, were then taped lightly to the ventral surface of the wrist and arm.

Recording and analysis. An exogenous constant current of 100 μa was passed through the electrodes by means of a constant current generator having total voltage capacity of 300 volts. The voltage recorded across the electrodes was fed into a logarithmic converter, and the log voltage amplified sufficiently to drive one channel of the seven-channel FM magnetic tape recorder (Ampex SP 300). One fifteen-minute sample of the basal skin-resistance of S was recorded each hour.

To analyze the data, the magnetic tape was played back (at eight times recording speed) to a voltage-to-frequency converter. The output of the converter was fed to an electronic counter which took seven ten-second samples from each data block. These samples totalled 9 min. and 20 sec. of the 15 min. real-time sample. The output of the counter, presented as a parallel BCD code, was serialized and punched on paper tape in eight-level serial BCD code. The paper tape was then fed to a reader, and the number of counts accumulated in each sample was automatically typed out on an electric typewriter.

Counts were translated into resistances by means of calibration tape prepared by using fixed resistors in place of the variable resistances produced by S. Mean log resistance was computed for each sample. For each S, the mean resistance of the first sample was subtracted from each successive sample to yield hourly GSR scores (mean Δ log R).

Results. Usable data on basal skin-resistance were obtained from 10 Ss, of whom only one remained in isolation for the entire 72-hour period.

In Fig. 4, the upper curve presents the mean GSR of all Ss plotted as a function of hours in isolation. The lower curve of Fig. 4 presents the mean GSR of all Ss as a function of objective or calendar time. For the upper curve, the mean Δ log R values were selected for each S on the basis of the actual number of hours S spent in the isolation chamber, while for the lower curve the points were selected on the basis of actual calendar time (Eastern Daylight Savings Time over the three days the S spent in isolation, i.e., first day, 7 PM EDST to third day, 7 PM EDST).

Fig. 4 demonstrates a generally declining basal skin-resistance over time in isolation and calendar time except for the end points of the isolation-time curve at which an increase is noted. This increase, however, may reflect a few extreme scores and the reduced N available for inclusion in the final data points. The product moment correlation between isolation time and basal skin-resistance irrespective of calendar time, was $-.32$ ($p < .01$).

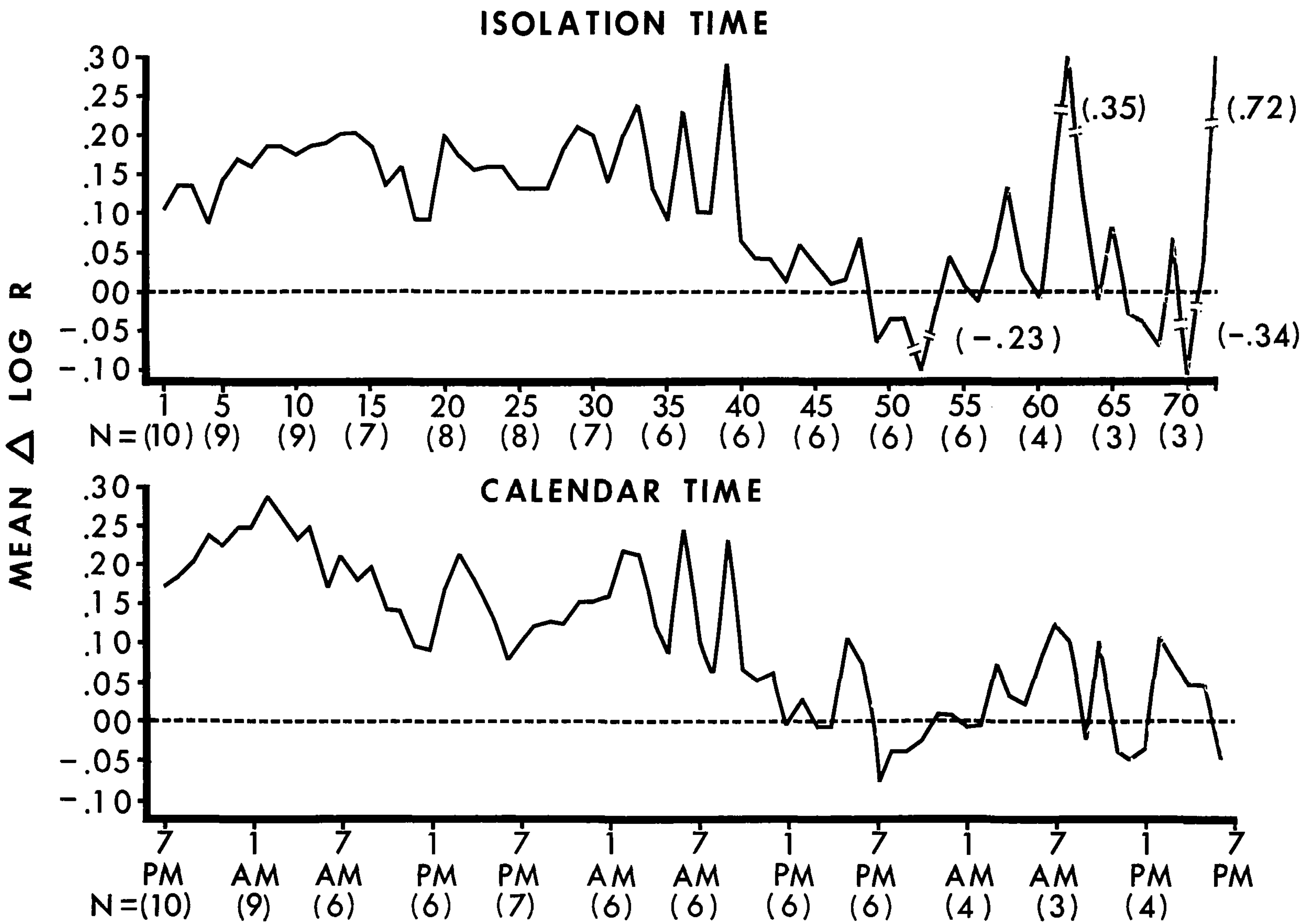


Fig. 4. Change in GSR as a Function of Isolation Time and Calendar Time

In order to determine whether basal skin-resistance changes follow a circadian pattern which is locked to a diurnal cycle, the product moment correlation between calendar time and basal resistance was computed. The resulting correlation ($\underline{r} = -.77$; $\underline{p} < .01$) indicates that when basal resistances are selected on the basis of calendar time, irrespective of the time Ss have been in isolation, the correlation of the resistance with time is much greater than when objective time is disregarded.

Inspection of Fig. 4 reveals three resistance peak-trough cycles of approximately 24 hour duration superimposed on a generally declining resistance function. The final peak on this curve again may reflect the higher basal resistance of the few Ss who remained in isolation for the entire 72 hours.

Most studies have indicated a negative relationship between time in isolation and basal skin-resistance levels (Zuckerman, 1964; Zuckerman, Levine and Biase, 1964) but these studies have dealt with short periods of isolation only, i.e., up to three hours. An earlier study by Silverman, et al. (1961) demonstrated increases in skin-resistance during isolation but their Ss, too, remained in isolation for only two hours. The latter results were confirmed by Cohen, et al. (1962) whose data on nonspecific GSR fluctuations parallel the earlier findings on basal skin-resistance for the two hour isolation period.

Vernon, et al. (1961) reported decreases in skin resistance from pre- to postisolation tests after 24, 48, and 72 hours, with the least decrease in resistance occurring after 24 hours, and the greatest decrease after 72 hours. In no previous study, however, was skin-resistance monitored continuously for periods up to 72 hours without interruption to apply electrodes.

In view of the Maulsby and Edelberg (1960) report that basal skin-resistance is inversely related to skin temperature, we examined the relationship between basal skin-resistance and ambient chamber temperature recorded during isolation since we would expect skin temperature to show some relationship to ambient room temperature. Since monitoring of the ambient chamber temperature had not yet been implemented during the time the resistance data were collected, 10 Ss were selected at random from those placed in isolation after temperature monitoring had been initiated.* The assumption was made that temperature variations experienced by this group of Ss would be equivalent to those experienced by the group wearing the skin-resistance electrodes since the groups were otherwise believed to be in equivalent environments.

For the data computed on the basis of isolation time, the correlation between room temperature and GSR was .23 ($p < .05$) and the correlation between GSR and isolation time with the ambient room temperature partialed out was -.25 ($p < .05$).

The correlation between GSR and ambient temperature computed on the basis of calendar time for the two groups of Ss was .53 ($p < .01$). The correlation between GSR and calendar time with the effect of ambient chamber temperature partialed out was -.66 ($p < .01$). Thus, basal skin-resistance demonstrated a highly significant negative relationship to calendar time during the course of isolation, irrespective of temperature variation while the relationship noted between isolation time and resistance was considerable weaker.

This autonomic activity, then, increased during isolation, but these increases seemed to demonstrate circadian variation and were time-locked to a 24-hour day. This, of course, may simply reflect the sleep-wake cycles of the Ss. Extended periods of isolation may tend to break down the regularity of this rhythmic activity, but this loss of the "synchronizer" may not be reflected in loss of periodicity for quite some time (Halberg, 1960; Lobban, 1960). Previous researchers examining autonomic activity seem to have largely ignored alteration of this rhythmic activity.

Electroencephalography (EEG)

Electrode attachment. Pretested** EEG electrodes were placed on S's scalp, in five specially prepared locations: vertex, midline occipital, dominant temporal, dominant sensorimotor, and midline inion (for ground). These sites yielded three biopolar recordings: vertex to occipital, vertex to dominant temporal, and vertex to dominant sensorimotor. The hair over each site was cut, and the scalp degreased with several applications of reagent-grade acetone. A commercial cosmetic

* During this period basal skin-resistance was not recorded.

** EEG electrodes were tested for offset potentials after allowing them to come to equilibrium in a saline solution; any electrode showing offset potentials of more than 5 mv. was rechlorided.

depilatory was then applied and allowed to remain on the area for 15–20 minutes after which S shampooed his hair with a hexachlorophene detergent. The skin over the site was then lightly touched several times with a dental burr (No. 6) mounted in a high speed (27,000 rpm) drill. Burring was repeated until S reported stinging when an acetone-saturated gauze sponge was applied to the site. The electrode (a Ag–AgCl stud set in a bakelite cap) was filled with an electrolyte paste having a NaCl base,* and glued over the prepared site with a methyl cyanoacrylate adhesive. A protective helmet of cotton wool and adhesive tape was individually created for each S and applied over the electrodes and leads. Additional foam rubber and padding (7.5 - 10 cm. thick) were used over the inion and occipital placements.

Recording and analysis. The EEG signals were amplified by an Offner Type-R Dynagraph and the signals recorded on three channels of the seven-channel FM magnetic tape recorder. EEGs from each S were recorded for 15 minutes each hour S was in isolation.

For data processing, a 12 min. sample of each 15 min. recording was played back at eight times the recording speed. The taped signal was first passed through a band-pass filter set at .2–35 cps which removed extraneous noise from the signal and amplified the filtered signal 10 times. The filtered, amplified signal was then fed to the amplitude discriminator (set at 0) of the Mnemotron Computer of Average Transients (CAT), which was set to the H program. In this program, the first positive crossing of the discriminator level by the EEG starts the address register of the computer. The next positive crossing stops the register, deposits one count in the channel addressed, resets the register to zero and, after 50 μsec. for a storage cycle, starts the address register again. This is repeated for each successive pair of positive crossings of the discriminator level unless successive crossings have a longer interval than the analysis time set on the computer. In this case the address register sets to zero, deposits one count in the zero channel and waits until the next positive crossing to start the register again. The resulting distribution is a plot of period, i.e., time between successive

*Paste designed for long-term recording by NASA (Day and Lippett, 1964) and provided for the grant without charge by Dome Chemical Co.

positive discriminator baseline crossing, against number of occurrences. Data were returned from the computer in an analog form or in a digital form (number of counts per address) on punched tape or as typewriter copy, and frequency, the reciprocal of period, was computed.

Results. Considerable difficulty was encountered in obtaining usable EEG records over the extended time period involved. Data, however, were available for 15 Ss. For these Ss, the mean time at which recordings were no longer available (due to early release of S or obscuration of the signal by excessive noise) was 27.5 hours. Data are reported below for two of the four Ss whose EEG records were usable for over 50 hours.

Figures 5 through 14 present for every sixth hour, the individual analog frequency plots of the data from the vertex-occipital lead of S No. 22 as they were obtained from the CAT. This S entered the isolation chamber at 3:34 PM and asked to end isolation after 57 hours. It may be noted that as time increased the peaks in the Beta frequency region (13-25 cps) became smaller or disappeared entirely, while activity in the Alpha frequency band (8-12 cps) became broader and less peaked. Theta activity (4-7 cps) too seemed to increase somewhat as S remained in isolation. This pattern indicated a general slowing of EEG activity during the course of isolation, mirroring a decrease in the level of cortical arousal for this S.

This decreasing arousal function may be seen more clearly in Fig. 15 in which the digital output of the CAT has been plotted. Beta activity showed a significantly declining function with time (rho = -.85, $p < .01$) while the slower activity of Delta (2 - 3.9 cps) and Theta showed rising but not significant functions. Alpha, however, did show a significant positive relationship with time in isolation (rho = .59, $p < .05$). The lack of significant changes in the Theta and Delta bands in the occipital area is not surprising in light of the studies by Zubek, et al. (1961) in which increased Theta activity was observed only in the temporal area in Ss undergoing isolation periods for as long as ten days. Increased Theta activity in the temporal area after one week of perceptual or sensory isolation was reported by Zubek & Welch (1963) and increased slow activity after 96 hours of isolation was noted by Heron (1961).

Fig. 5

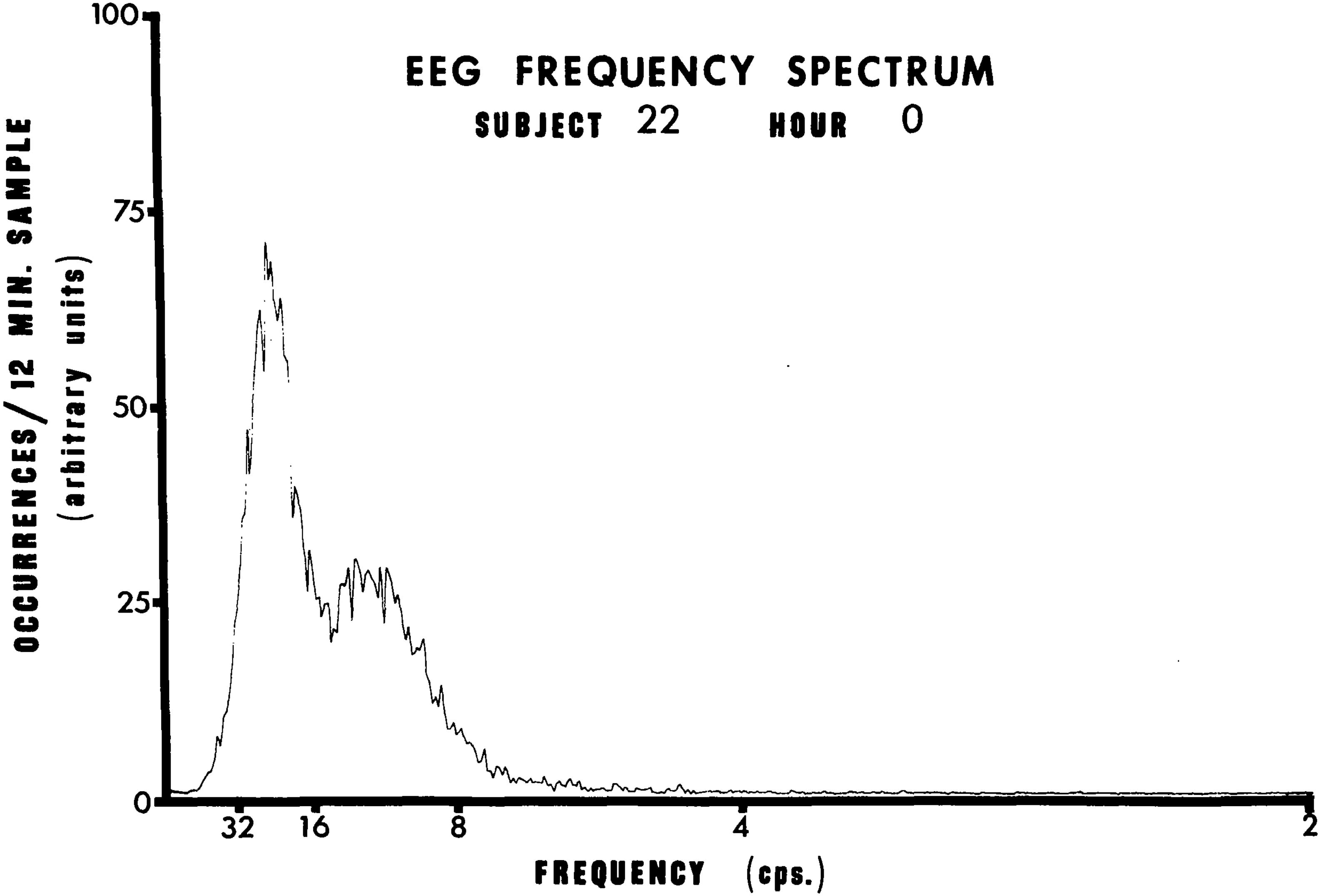

EEG FREQUENCY SPECTRUM
SUBJECT 22 HOUR 0
OCCURRENCES/12 MIN. SAMPLE
(arbitrary units)
100
75
50
25
0
32
16
8
4
2
FREQUENCY (cps.)

Fig. 6

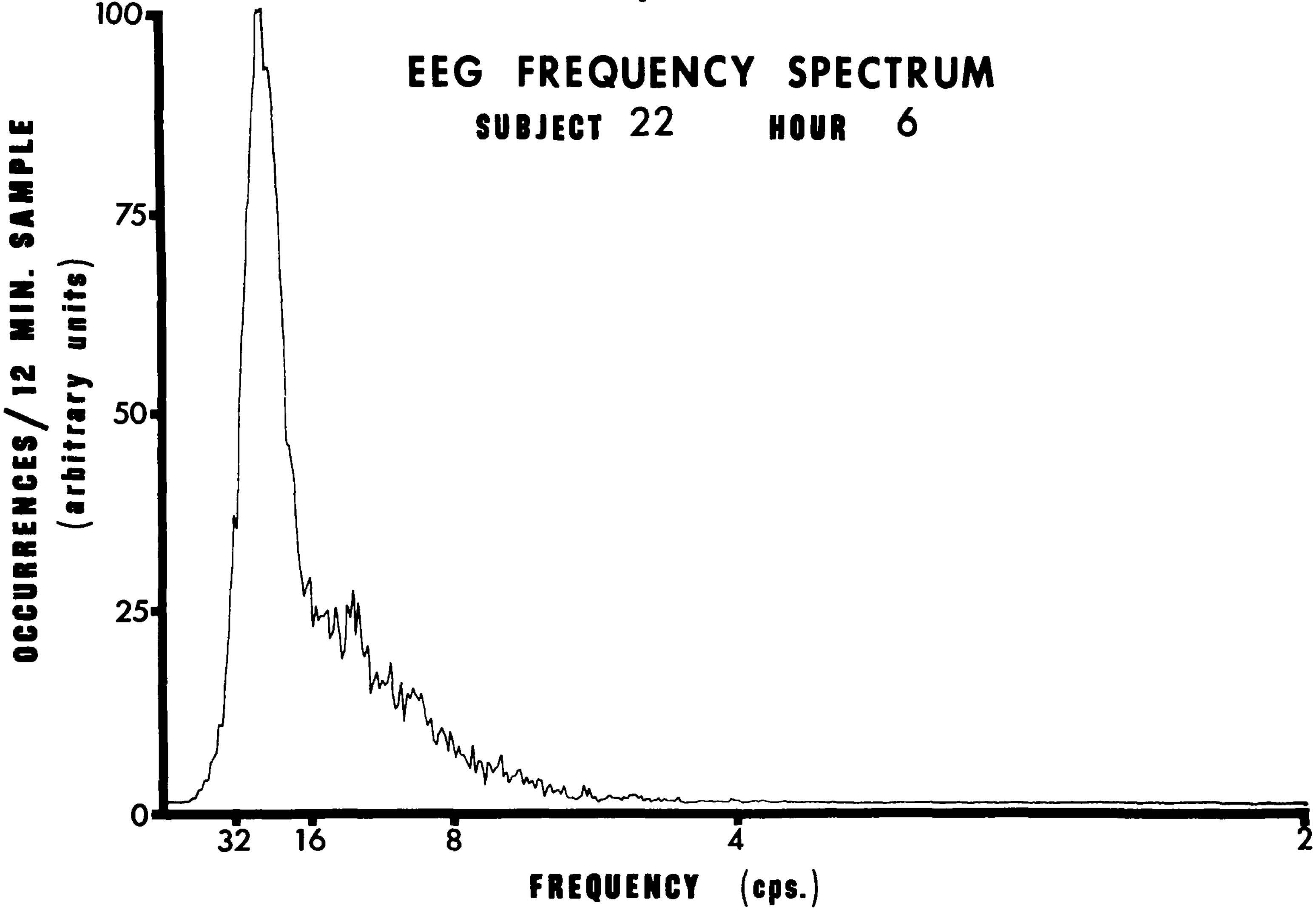

EEG FREQUENCY SPECTRUM
SUBJECT 22 HOUR 6
OCCURRENCES/12 MIN. SAMPLE
(arbitrary units)
100
75
50
25
0
32
16
8
4
2
FREQUENCY (cps.)

Fig. 7

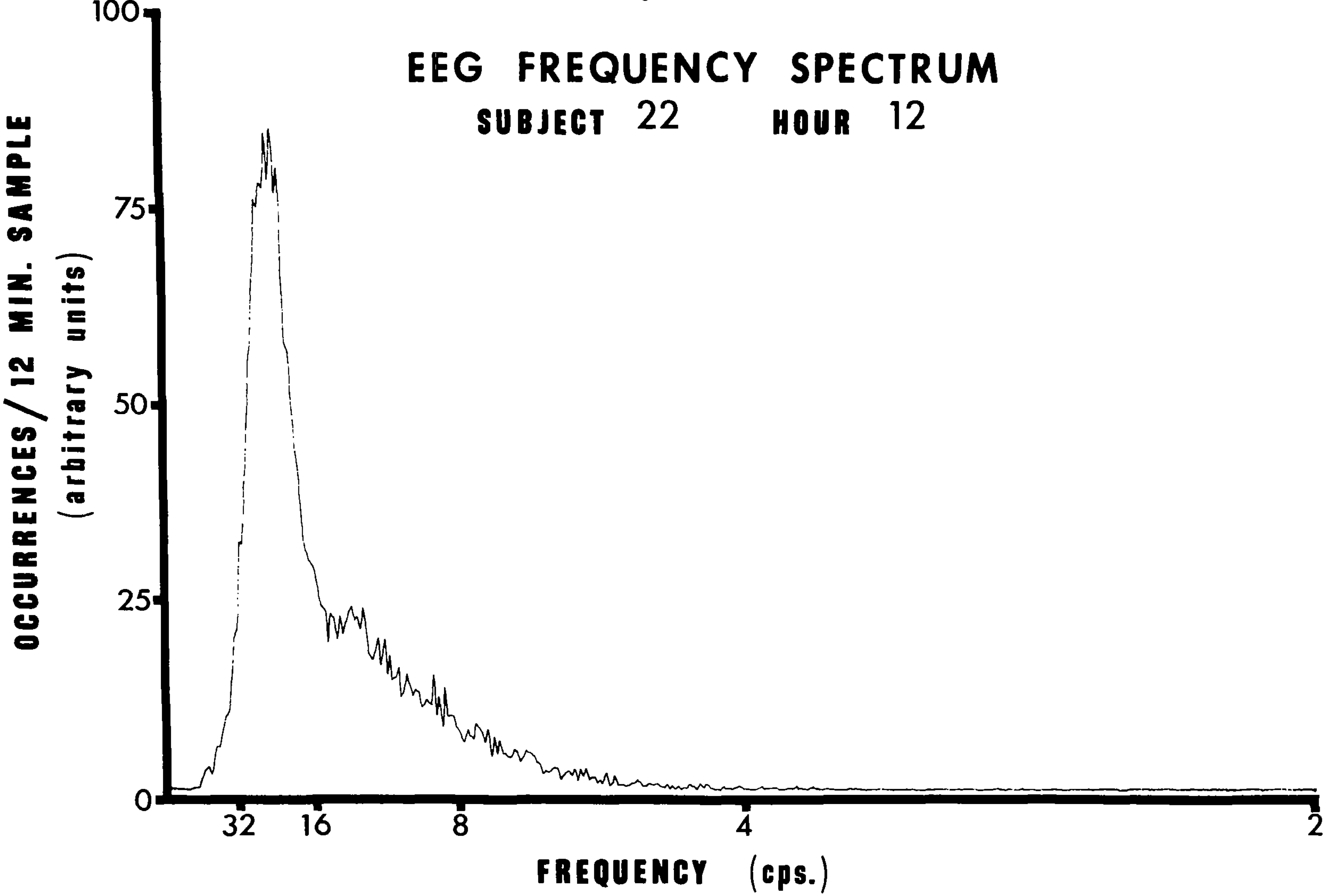

EEG FREQUENCY SPECTRUM
SUBJECT 22 HOUR 12
OCCURRENCES/12 MIN. SAMPLE
(arbitrary units)
100
75
50
25
0
32
16
8
4
2
FREQUENCY (cps.)

Fig. 8

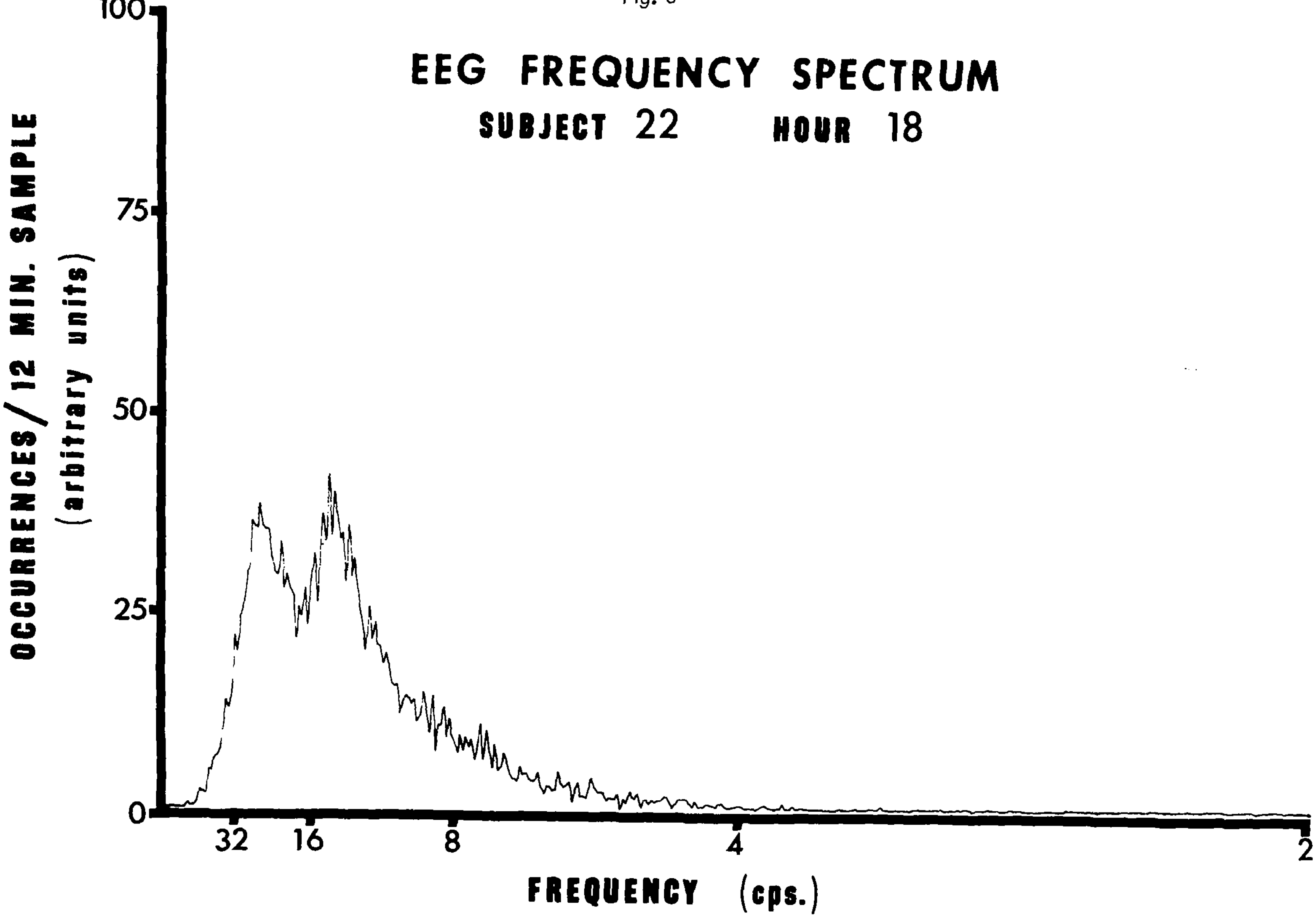

EEG FREQUENCY SPECTRUM
SUBJECT 22 HOUR 18
100
75
50
25
0
OCCURRENCES/12 MIN. SAMPLE
(arbitrary units)
32
16
8
4
2
FREQUENCY (cps.)

Fig. 9

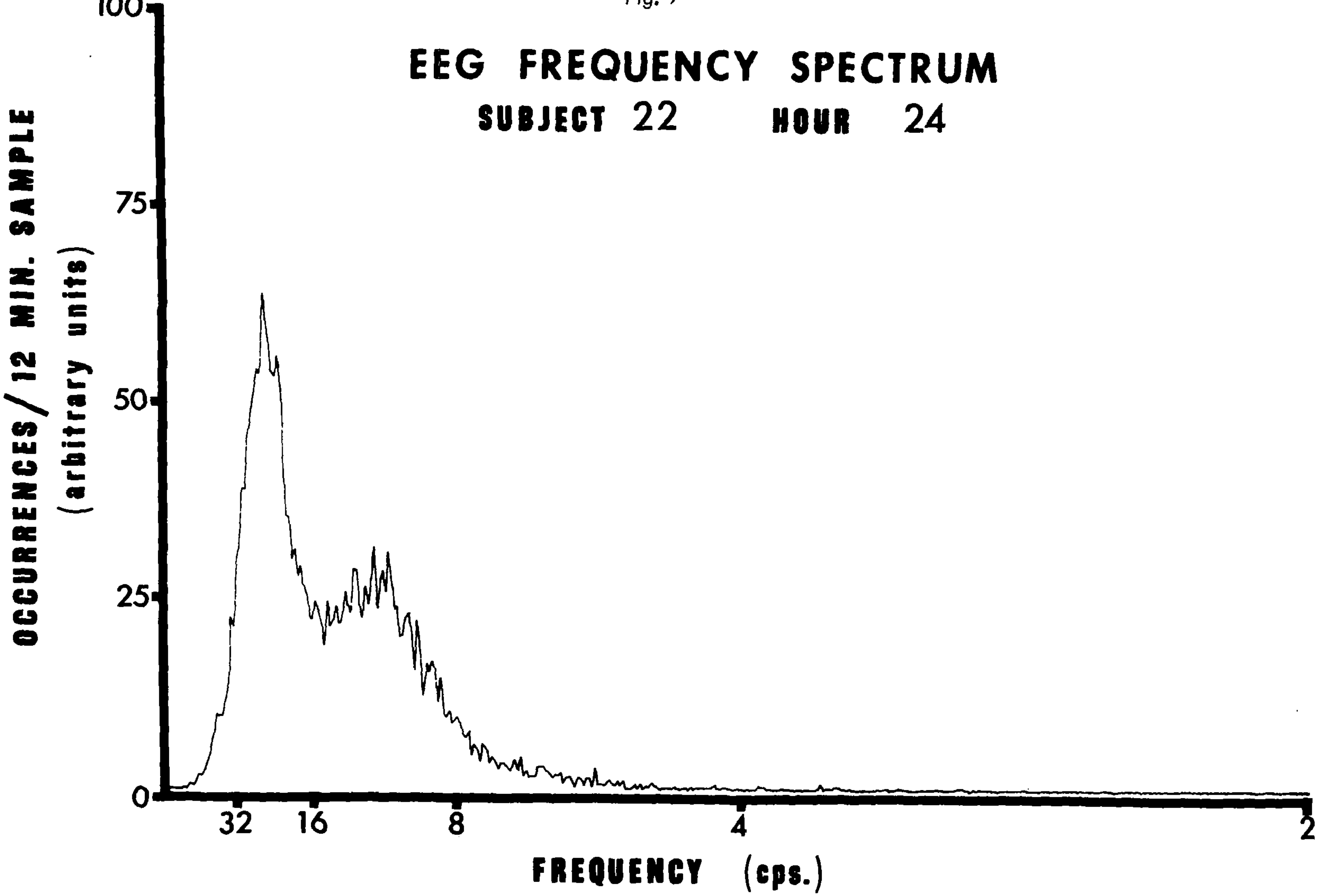

EEG FREQUENCY SPECTRUM
SUBJECT 22 HOUR 24
OCCURRENCES / 12 MIN. SAMPLE
(arbitrary units)
100
75
50
25
0
32
16
8
4
2
FREQUENCY (cps.)

Fig. 10

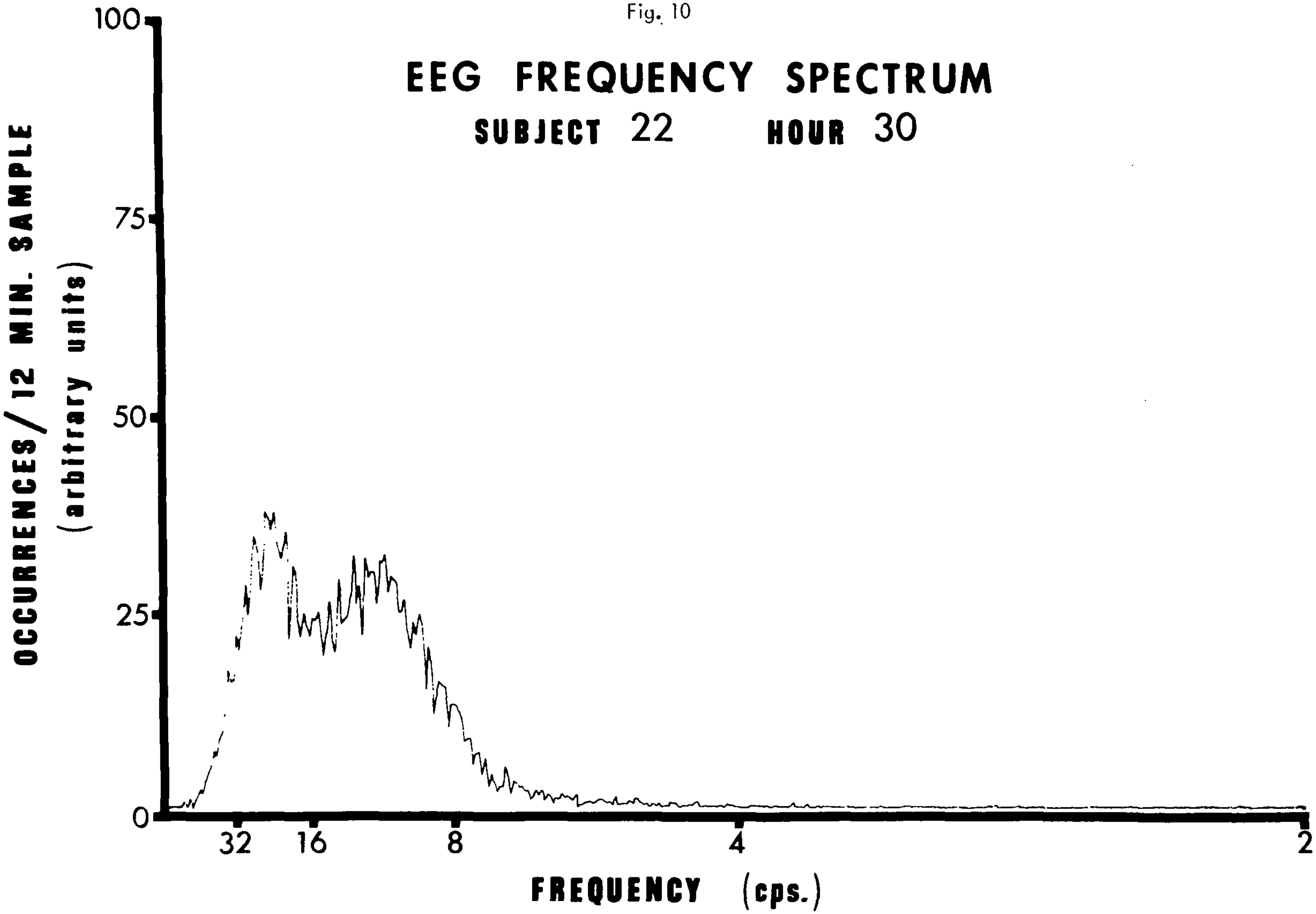

EEG FREQUENCY SPECTRUM
SUBJECT 22 HOUR 30
OCCURRENCES/12 MIN. SAMPLE
(arbitrary units)
100
75
50
25
0
32
16
8
4
2
FREQUENCY (cps.)

Fig. 11

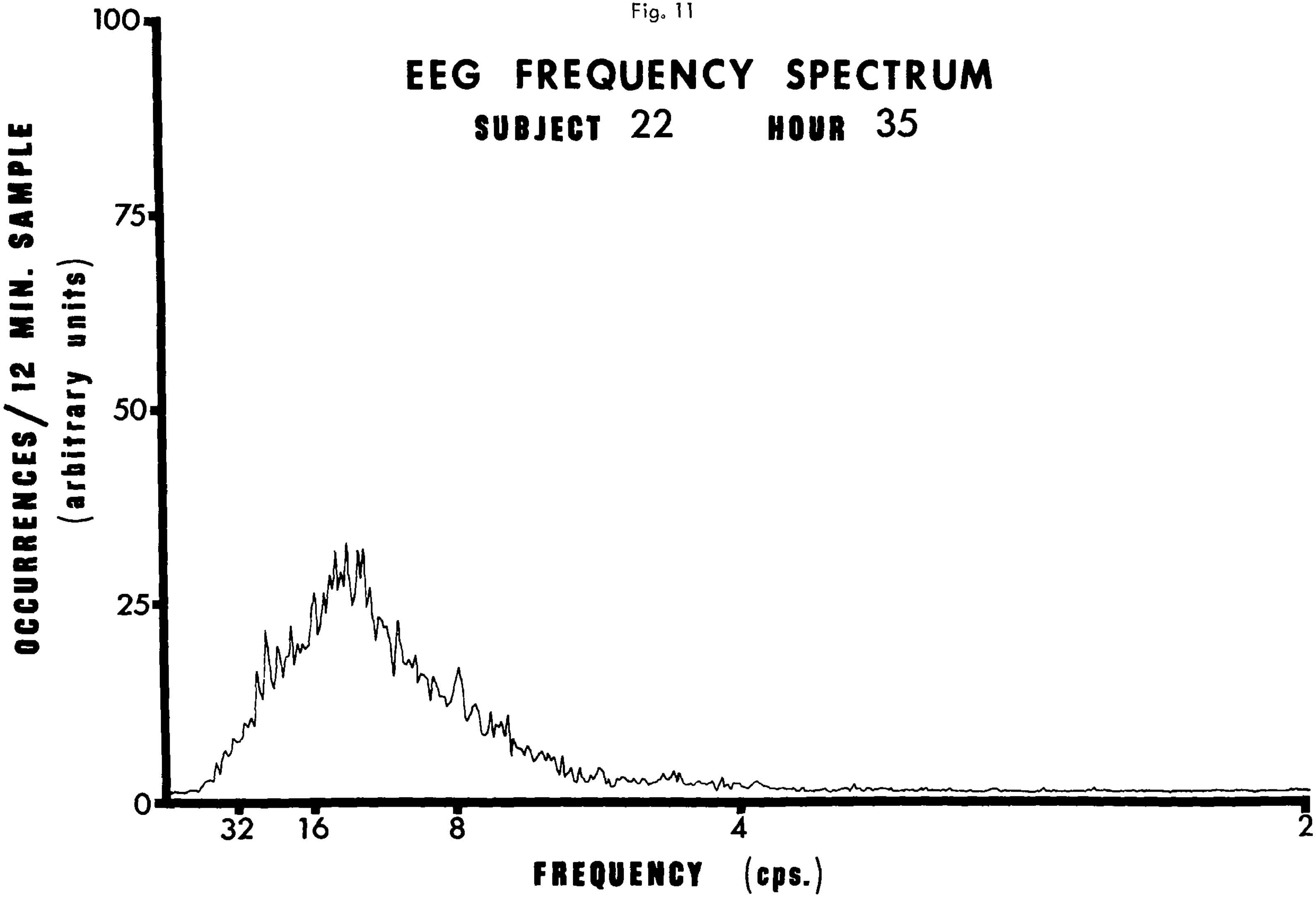

EEG FREQUENCY SPECTRUM
SUBJECT 22 HOUR 35
OCCURRENCES/12 MIN. SAMPLE
(arbitrary units)
100
75
50
25
0
32
16
8
4
2
FREQUENCY (cps.)

Fig. 12

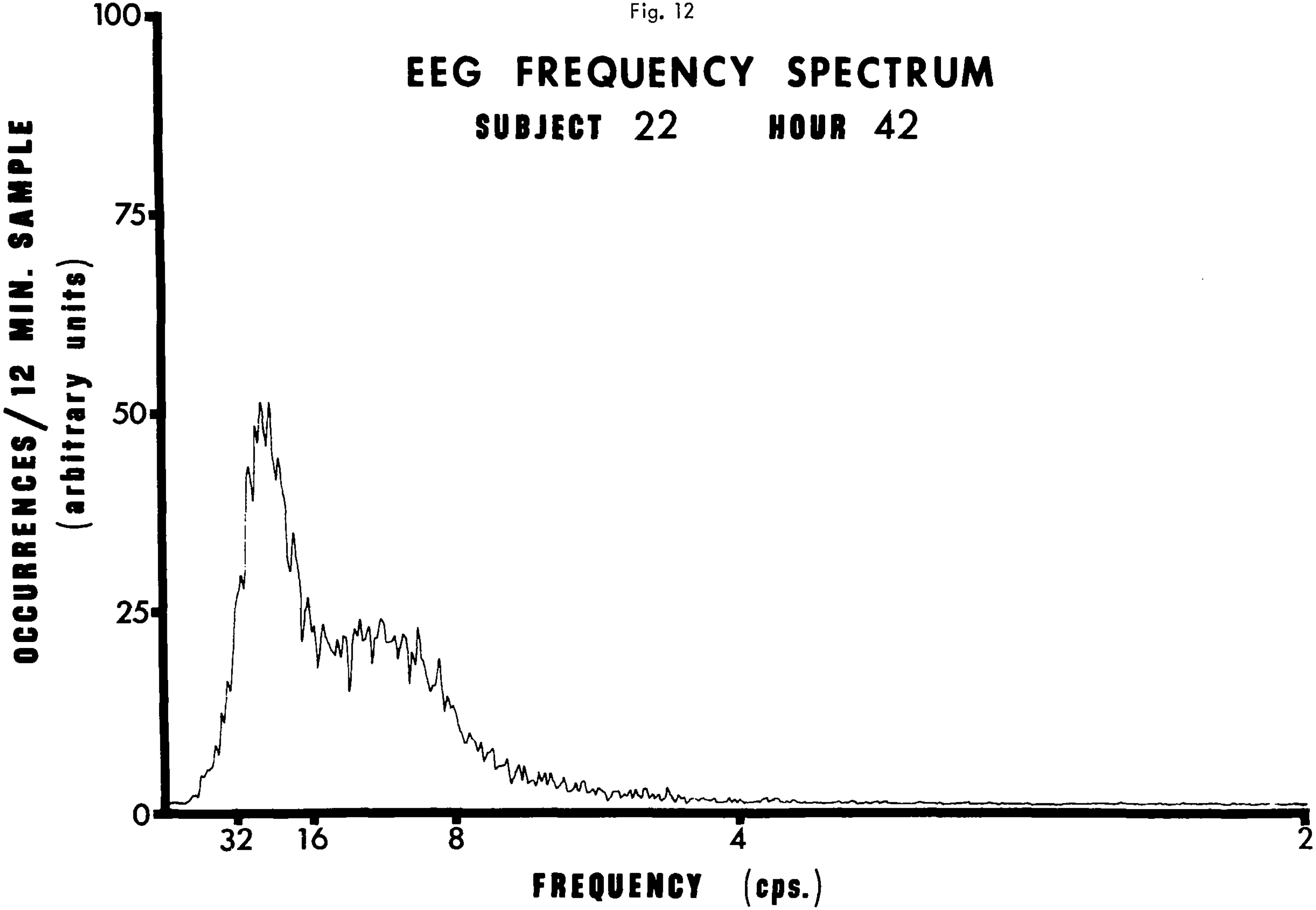

EEG FREQUENCY SPECTRUM
SUBJECT 22 HOUR 42
OCCURRENCES/12 MIN. SAMPLE
(arbitrary units)
100
75
50
25
0
32
16
8
4
2
FREQUENCY (cps.)

Fig. 13

EEG FREQUENCY SPECTRUM

SUBJECT 22 HOUR 48

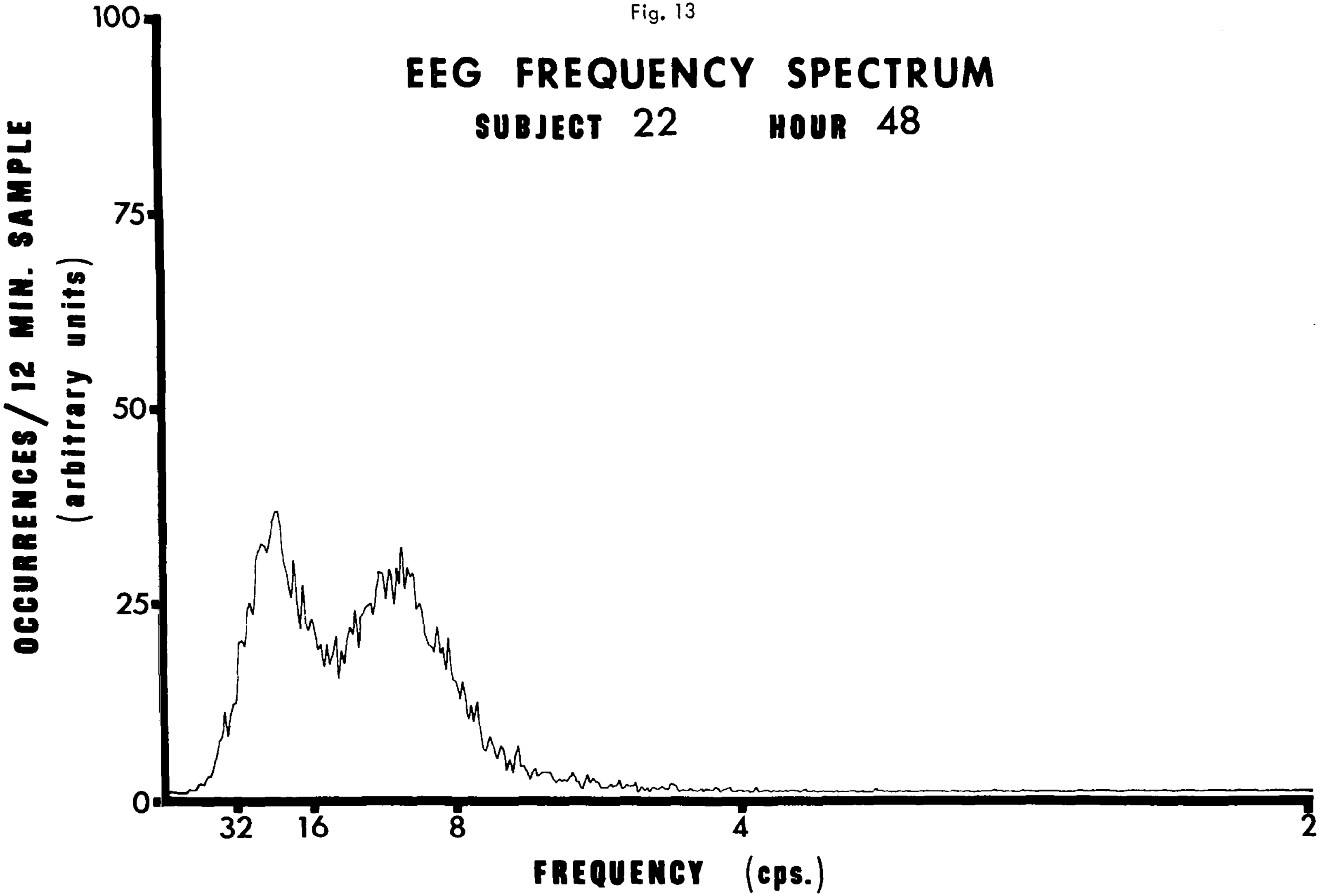
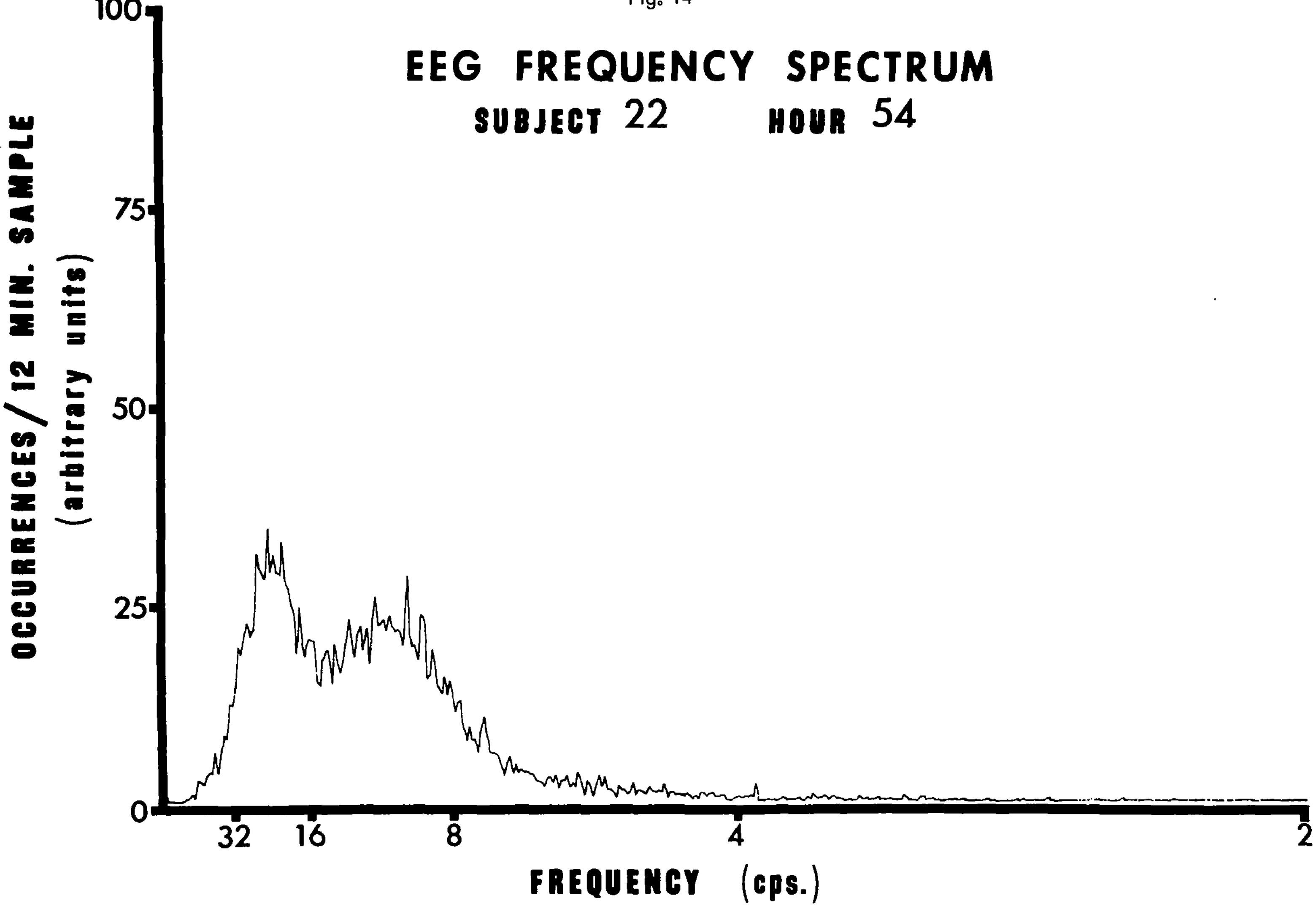


Fig. 14


EEG FREQUENCY SPECTRUM
SUBJECT 22 HOUR 54
OCCURRENCES / 12 MIN. SAMPLE
(arbitrary units)
100
75
50
25
0
32
16
8
4
2
FREQUENCY (cps.)

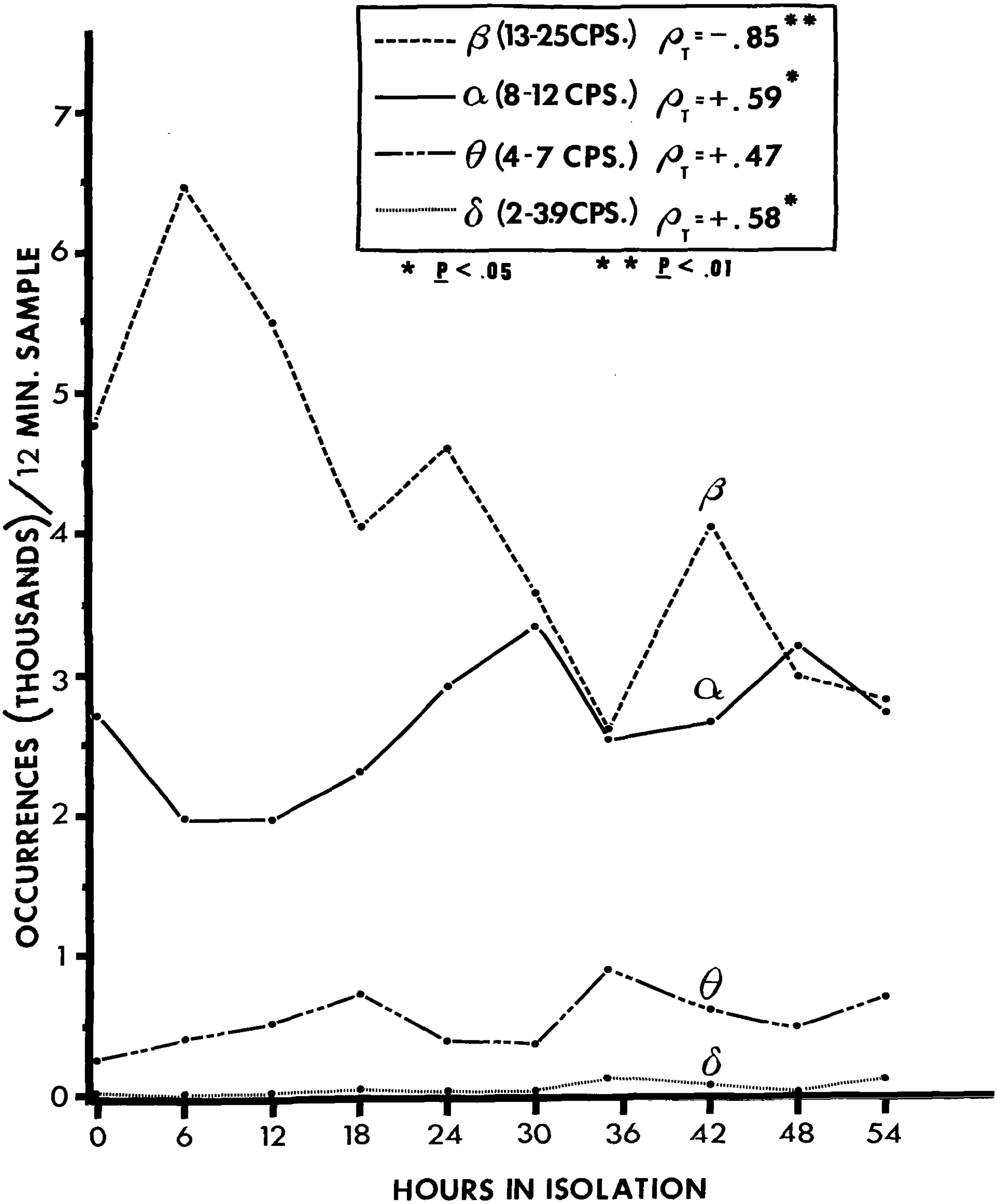


Fig. 15. Changes in EEG Frequency Bands During the First 54 Hours in Isolation. (S 22; Total Isolation 57 Hours)

Nagatsuka and Kokubun (1964) reported that little activity either in the Beta or Delta range was exhibited by Ss in isolation. Rather, most activity was in the Alpha and Theta frequency region.

In several studies, decreases in mean frequencies recorded over the occipital region were noted under a variety of conditions of isolation (Zubek, 1963; Zubek and Welch, 1963; Zubek, Welch, and Saunders, 1963; Zubek and Wilgosh, 1963; Zubek, 1964a). These studies indicated a progressive slowing of frequencies in the Alpha band. Our data (Table 6) from S 22 similarly indicates this slowing over 54 hours.

Table 6

Initial and Final Percentages in Alpha Frequency Spectrum (S 22)

Alpha Freq. (cps)	Hour 1	Hour 54	Change
8	18.62	27.33	+8.71
9	18.15	20.16	+2.01
10	27.25	24.63	-2.62
11	21.50	16.84	-4.66
12	14.48	11.05	-3.43

S 22 then, exhibited a decreasing level of arousal during the course of isolation.

While most studies have indicated decreasing EEG arousal with sensory isolation, great individual variation has been reported (Zubek, 1964a). In light of the large individual variations reported, it is not entirely surprising that data collected from S 21 showed a change of EEG activity in the opposite direction demonstrated by S 22.

The curve of the digital data of S 21 (Fig. 16) indicates significantly decreasing Alpha (rho = -.73, $p < .01$) and Delta activity (rho = -.58, $p < .05$), nonsignificantly decreasing Theta activity (rho = -.50) and a nonsignificantly rising Beta function (rho = .42) with time in isolation. These changes indicate a slightly increasing arousal level. Studies by Silverman (1961) and

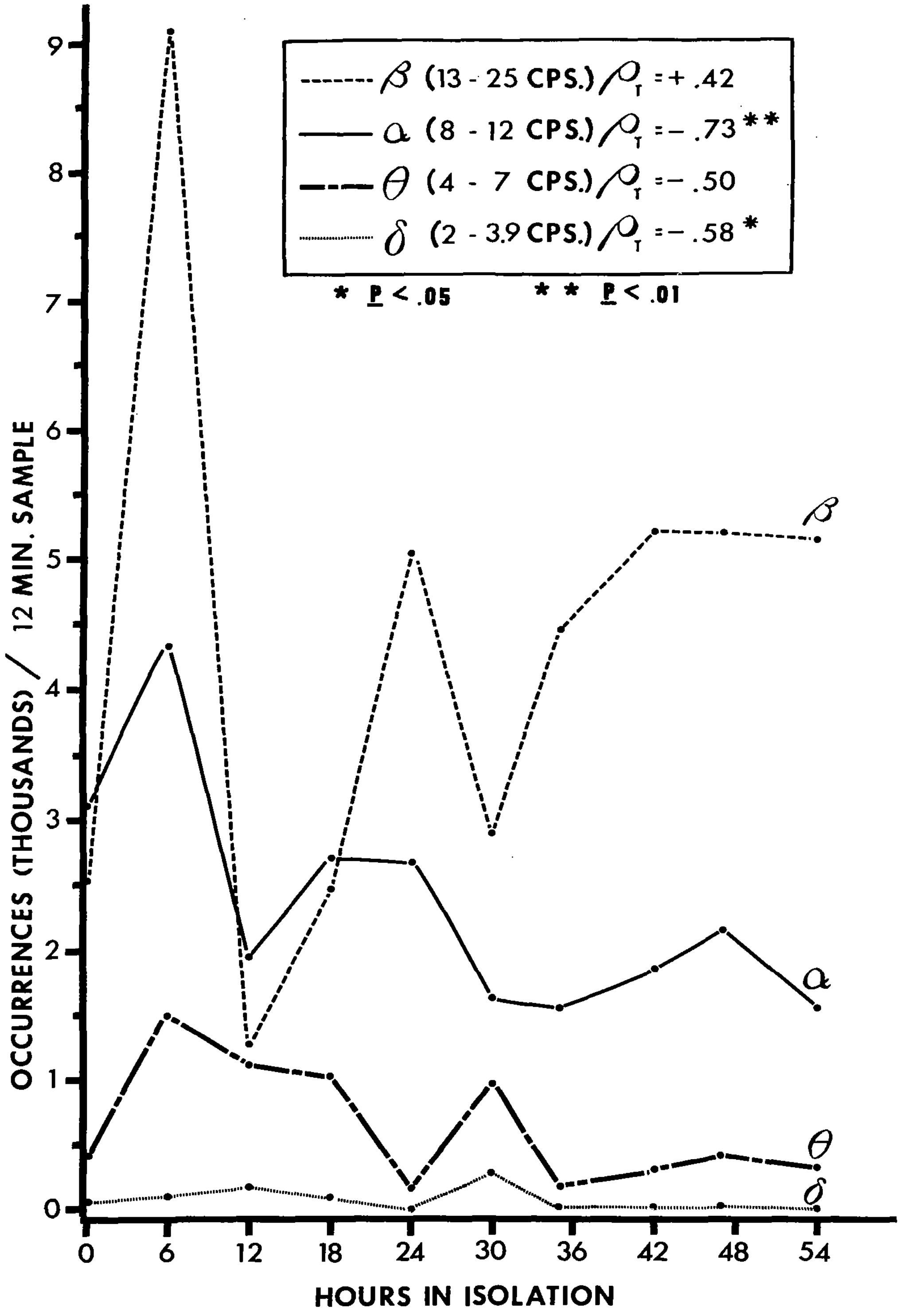


Fig. 16. Changes in EEG Frequency Bands During the First 54 Hours in Isolation. ($\underline{S}$ 21; Total Isolation 72 Hours)

Cohen, et al. (1962) indicate a tendency for the more cortically-aroused Ss to request early release from isolation. S 21 remained in isolation for the entire 72-hr. period. Table 7 shows the frequency shifts within the Alpha band, and indicates increased EEG arousal.

Table 7

Initial and Final Percentages in Alpha Frequency Spectrum (S 21)

Alpha Freq. (cps)	Hour 1	Hour 54	Change
8	19.1	18.4	-0.7
9	18.8	18.6	-0.2
10	24.8	18.5	-6.3
11	22.5	29.3	6.8
12	14.9	15.1	0.2

Under the assumption that indicators of autonomic nervous system arousal and cortical arousal may be positively correlated, correlations between Beta activity and skin conductance were calculated. For S 21 the rho was +.32, which was not significant, although in support of the assumption. However, for S 22, the rho was -.15, again not significant, but opposite in direction to the assumption. While these data, as well as the other EEG data presented here are those of only two Ss, it is clear that individual differences have been demonstrated. The major task of using EEG as a predictor variable for the other behavioral measures remains to be accomplished.

Hand Temperature

A measure of hand temperature was introduced into the test battery as a potential control or covariate. The measure was obtained by hanging a Hartman and Braun Thermocouple on the distal phalanx of the fourth finger of the supinated nonpreferred hand. Constant pressure was thus placed on the wire. The temperature was recorded to the nearest .5C°.

Results. The difference in hand temperature after isolation in each of the groups is presented in Table 8, along with the results of the tests of significance.

There were no significant differences between the groups, nor were any other comparisons significant.

Table 8

Hand Temperature

Groups	$\underline{N}$	$\underline{M}_d$	$\underline{t}_d$	$\underline{t}_c$	$\underline{t}_e$
Control	22	0.28	0.35	-	-
72-hour	16	-0.76	0.58	.72	1.37
< 72-hour	17	1.40	1.55	.94	

Note. $\underline{M}_d$ cell entries are in C°

$\underline{N}$ = Number of Ss

$\underline{M}_d$ = Mean difference (postisolation mean minus preisolation mean)

$\underline{t}_d = \underline{t}$ for $\underline{M}_d$

$\underline{t}_c = \underline{t}$ for difference between $\underline{M}_d$ for Isolation group and $\underline{M}_d$ for Control group

$\underline{t}_e = \underline{t}$ for difference between $\underline{M}_d$ for 72-hr. group and $\underline{M}_d$ for < 72-hr. group

Metabolic Variables

A number of measures related to general metabolic functioning have been obtained which may be of future use for covariance analyses. That is, although it was not predicted that body weight, food and water consumption, or excrement weight would be affected by sensory deprivation, per se, they might, however, be affected by the particular techniques of the present experiment, and could therefore be a factor in any changes in the primary dependent variables.

Although the covariance analyses have not been completed, some of the normative data for the variables are presented below.

Ss were provided with a supply of 30 cans of liquid food* in .47 liter cans and three 454 gm. loaves of bread** containing 20 slices. These food supplies were placed in the chamber prior to S's isolation. They were immediately adjacent to S and could be reached with a minimum of movement. A special can opener was provided which could be operated with one hand. Three plastic jars containing 3.78 liters of water were placed immediately adjacent to S, next to the food. A plastic straw was used by S to obtain the water. Ss were on an adlibitum diet which, because of its sufficiency, required no intervention by E.

Ss were weighed before and after isolation with a Detecto scale, accurate to approximately 110 gm. Once S was weighed, he was instructed to use the toilet in his cubicle exclusively until he was reweighed after isolation. Weight measures were obtained while S was wearing pajamas.

The chemical toilet in the chamber was weighed before and after isolation on the Detecto scale, the difference indicating the weight of S's excreta during isolation .

Table 9 summarizes the results for the metabolic variables.

Table 9

Metabolic Variables

		Means					
Groups	N	Hours in Isolation	Weight Decrease (kgm.)	Bread Consumed (gms.)	Liquid Diet Consumed (liters)	Water Consumed (liters)	Excreta (kgm.)
< 24 hours	8	12.6	0.49	354	0.47	0.28	0.05
24-47 hours	6	27.7	0.95	295	1.88	0.83	1.27
48-71 hours	8	55.5	2.09	418	4.23	1.66	2.72
72 hours	22	72.0	1.72	454	4.20	2.22	2.65

Note. Each 100 gms. of bread provided 286 calories; each liter of liquid diet provided 479 calories.

---

* "Metrecal" produced by Mead Johnson Company

** "Brick Oven White Bread," produced by Arnold Bakers Co.

The only surprising aspect of Table 9 was the marked similarity in results for the 72-hr. and 48-71 hr. groups. Apparently spending an additional 16.5 hours (on the average) in the isolation chamber produced little or no change in the metabolic variables.

Since control data were available on weight change, this variable was analyzed in greater detail. The Control group showed a slight (.39 kgm.) nonsignificant gain in body weight. Both the 72-hr. group and the 48-71 hr. group showed a significant decrease in weight which was, in each case, significantly different from the Control group. The 72-hr. group showed a significantly greater weight loss than the combined <72-hr. groups. However, this difference is attributable mainly to those Ss who spent relatively few hours in isolation (Table 9).

The observed weight loss in the present study was, for the most part, expected. Vernon, et al. (1961) reported loss in body weight during isolation even when the diet allowed was more varied and the Ss consumed considerable quantities of food. In that study, Ss lost an average of 2.5 pounds (1.14 kgm.) following 72 hours of isolation. In the present study, with a more restricted diet, the weight loss following the 72 hours of isolation was somewhat greater.

3. Cognitive Variables

The preisolation test battery began with three tests taken from the Employee Aptitude Survey (EAS) battery*. For each test, Form A was administered before, Form B after isolation.

Verbal Comprehension

This is a five minute, self-administering vocabulary subtest. The test constructors describe the test's purpose as follows:

"...measures the ability to use words meaningfully, in communication, thinking, and planning. Performance on this test is highly indicative of reading speed and ability to understand written or spoken instructions. Verbal ability is the most important single aspect of 'general intelligence.'"

*Developed by Psychological Services, Inc., Los Angeles, Calif.

Table 10 presents the mean changes in verbal comprehension for all groups. It can be seen that there were neither significant changes within any group, nor significant differences between groups for this measure.

Table 10

Verbal Comprehension

Groups	N	M_d	t_d	t_c	t_e
Control	22	0.26	0.54	-	-
72-hour	21	-0.05	0.06	0.34	0.37
< 72-hour	19	-0.44	0.62	0.84	

Note. Mean cell entries are based on the number right for Form A (Pre-) and the number right corrected for repeated testing on Form B (Postisolation): See Table 8 for explanation of symbols.

Previous reports of verbal functioning have shown varied results depending upon the type and duration of deprivation employed, as well as the type of verbal functioning tested. In general, verbal fluency is impaired by prolonged perceptual deprivation or prolonged severe immobilization. Verbal fluency is not affected, however, by sensory deprivation, and the deficits that do occur with perceptual deprivation can, for the most part, be eliminated by exercise. On the other hand, verbal reasoning is generally unimpaired by either sensory or perceptual deprivation. In the present study verbal comprehension was unimpaired following 72 hours of sensory deprivation. Verbal comprehension is probably more comparable to verbal reasoning than to verbal fluency, but in either case these results are consistent with previous findings of studies using sensory rather than perceptual deprivation.

Visual Pursuit

This EAS subtest measures speed and accuracy in tracing a line visually through an entangled network of lines. It measures

"... a special type of perceptual ability which is important for... personnel whose work requires the use of complex schematic diagrams."

The time limit for this self-administering test was five minutes.

Table 11 presents the mean difference after isolation on the Visual Pursuit Test for each group and the results of the t tests. The Control and the < 72-hr. Isolation group showed significant improvement in the visual pursuit task. The 72-hr. group showed slight, nonsignificant improvement in the task. However, none of the groups comparisons were significant.

Table 11

Visual Pursuit

<table>
<tr><th>Groups</th><th>N</th><th>M_d</th><th>t_d</th><th>t_c</th><th>t_e</th></tr>
<tr><td>Control</td><td>22</td><td>1.66</td><td>2.92**</td><td>-</td><td>-</td></tr>
<tr><td>72-hour</td><td>21</td><td>0.31</td><td>0.38</td><td>1.37</td><td rowspan="2">1.25</td></tr>
<tr><td>< 72-hour</td><td>20</td><td>1.58</td><td>2.61*</td><td>0.10</td></tr>
</table>

Note. Mean cell entries are based on the number right for Form A (Pre-) and the number right corrected for repeated testing for Form B (Postisolation). See Table 8 for explanation of symbols.

* $p < .05$ ** $p < .01$

A cancellation test used by Zubek and his collaborators appears to be somewhat comparable to the Visual Pursuit Test employed in the present study. The previous research using the cancellation tasks indicates that both sensory and perceptual deprivation produce an impairment on this test. However, for sensory deprivation, the impairment did not occur until after four days of deprivation; as in the present study, three days of deprivation showed no significant impairment (Zubek, et al., 1960). It has also been shown that performance on the cancellation test is unimpaired by 24 hrs. of immobilization, (Zubek, Aftanas, Kovach, Wilgosh & Winocur, 1963), is impaired by seven days of immobilization (Zubek & Wilgosh, 1963), and is the only test that continues to show impairment when Ss are allowed to exercise during perceptual deprivation (Zubek, 1963). In the present experiment, there was significant improvement for the <72-hr. and Control groups, indicating that a practice effect may be operating. Since the 72-hr. Isolation group showed the smallest amount of improvement, it is possible that this finding may indicate some impairment in performance, in line with Zubek's findings.

Space Visualization

This EAS test,

"... measures the ability to visualize forms in space and manipulate objects mentally .... Space visualization is a strong component of 'mechanical aptitude.' "

This self-administering test had a five minute time limit.

The differences after isolation and the results of the t tests for Space Visualization are presented in Table 12. There was a significant postisolation improvement shown by the Control group, indicating the operation of a practice effect. Although the Isolation groups did not differ significantly from the Controls, or from each other, the attenuation of the practice effect was greatest in the 72-hr. group, which is similar to the finding for the Visual Pursuit Test (Table 11).

Table 12

Space Visualization

Groups	N	M_d	t_d	t_c	t_e
Control	23	2.24	2.61*	-	-
72-hour	21	-1.19	0.65	1.76	0.79
< 72-hour	20	0.44	0.49	1.45	

Note. Mean cell entries are based on the number right for Form A (Pre-) and the number right corrected for repeated testing on Form B (Postisolation). See Table 8 for explanation of symbols.

* $p < .05$

Previous research, mainly by Zubek and his collaborators, has indicated that spatial relations or space visualization is impaired by prolonged perceptual deprivation or prolonged severe immobilization, but unimpaired by prolonged sensory deprivation. The impairment under perceptual deprivation can also be eliminated with exercise. The results of the present study, consistent with previous studies of sensory deprivation, show that 72 hours of such deprivation does not significantly affect space visualization.

Time Estimation

A "production" method of time estimation was utilized (Wallace and Rabin, 1960). S was required to estimate ten consecutive 10-second periods of unfilled time. E utilized a time-and-motion study-board, which consisted of a clipboard and three stop-watches. The elapsed time of each of the estimated 10-second intervals was recorded. The following instructions were read to S:

"We are going to measure your ability to estimate time. When I say 'start' you will estimate 10-second intervals by counting to yourself and tell me when each interval is finished. When the first 10-second interval is over, you will say 'now' and start counting for the second 10-second interval. When the second interval has passed, you will say 'now,' etc. until you are asked to stop."

Table 13 presents the mean changes in time estimation after isolation for each group as well as the results of the various analyses.

Following isolation, all groups tended to show reduced average deviation (AD). However, this tendency was not significant, nor were there any significant differences between groups for AD.

With regard to the sign of the deviation (CD), all groups tended to overestimate the standard 10-second period before isolation.* The respective group means for Controls, 72-hr., and < 72-hr. Ss were: 10.84, 11.05, and 10.64 sec. The group means on posttesting were 10.87 for Control, 10.82 for 72-hr. and 9.28 for < 72-hrs. Ss. Thus, the < 72-hr. group was the only one to underestimate the 10-second standard after isolation (subjective temporal units smaller than objective ones). Their change in CD was significant and significantly different from that of the Controls.

Previous studies of time estimation in isolation research can be divided into two major categories: In the first, S is asked to estimate the day and time of day at various points during the isolation procedure, and in the second, S is asked

* For the production method of time estimation, overestimation indicates that the subjective temporal units were larger than objective temporal units. (Zubek, et al., 1961)

Table 13

Time Estimation

A. Average Deviation

Group	N	M_d	t_d	t_c	t_e
Control	22	-0.52	1.37	-	-
72-hour	21	-0.16	0.65	0.80	1.23
< 72 -hour	21	-0.75	1.82	0.41	

B. Constant Deviation

Control	22	0.03	0.06	-	-
72 -hour	21	-0.23	0.61	0.44	2.00
< 72-hour	21	-1.36	3.25**	2.27*	

Note. Mean cell entries are in sec. See Table 8 for explanation of symbols.

* $p < .05$, ** $p < .01$

to indicate at various points during isolation when an interval specified by E (e.g., 10 sec. or 120 min.) has passed.

For estimates of time spent in isolation the results have, in general, shown a tendency toward underestimation of the interval. This was true for perceptual deprivation (Goldberger & Holt, 1958) and for sensory deprivation (Vernon & McGill, 1963; Zubek, et al. 1961).

In studies involving estimation of specified intervals of time, other investigators have not employed pre-postisolation comparisons of accuracy. Zubek, et al. (1961) found a significantly greater underestimation of a 120 min. interval in isolation Ss compared with controls, but no significant differences in the estimation of shorter intervals. In a study employing 2 hours of visual deprivation (Mitchell, 1962) Ss reported that 10 seconds had elapsed after an actual period of 10.77 sec.

In the present study, the Constant Deviation for the Isolation groups showed a general decrease in overestimation from the pre- to the posttest.

The fact that the < 72-hr. group changed significantly from overestimation in the preisolation test to underestimation in the postisolation test seems to confirm the finding of Murphy, et al. (1962). These investigators required Ss to estimate the time spent in isolation and found that after 4 hrs. in isolation Ss who later requested early release showed significantly greater overestimation of time passage (smaller subjective temporal units) than Ss who remained for the full 96-hr. isolation period.

Adjective Checklist

An adjective checklist* was administered to Ss before and after isolation. The list consisted of the following 15 words or phrases: scared stiff, timid, steady, wonderful, comfortable, nervous, unsafe, terrible, worried, in agony, indifferent, frightened, unsteady, fine, doesn't bother me.

During the preisolation administration, S was instructed to place a check mark next to any word which was appropriate in describing his present feelings. In the postisolation session, S was asked to check any word which was appropriate to specific time periods. These time periods were: before isolation, beginning of isolation, during isolation, after isolation.

The principal interest in the adjective checklist was to determine whether isolation was seriously disturbing to the S. The checklists of those Ss who were used in the postisolation interview analysis were scored for "disturbance." A disturbance-response was counted whenever S checked any one of the following four words or phrases: scared stiff, terrible, in agony, and frightened.

The results of the analysis are shown in Table 14.

The results indicate that for the majority of Ss, isolation in general produced no disturbed feelings. However, about one-third of the two groups remaining in isolation longest did feel seriously disturbed during the isolation period. Since few of those Ss leaving isolation early reported such feelings, it would indicate that it was

* This list was provided by T. I. Myers (1964, personal communication)

Table 14

Adjective Checklist

Hours in Isolation			Percentage of Ss Reporting				
			Disturbed Feelings re: Isolation				No Disturbance
Range	M	N	Before	Beginning	During	After	
3-22	11.6	7	14	0	14	0	72
26-32	28.0	6	0	0	17	17	67
48-60	53.6	11	9	0	36	0	55
72	72	27	4	0	33	0	63

not the onset of disturbed feelings which led S to leave isolation early.

Zuckerman and his associates (1962) have studied anxiety in Ss isolated in an iron lung for seven hours. Utilizing an extensive (61 adjective) checklist (Zuckerman, 1960) they found that isolation increased anxiety in a group of women over that of controls (confined without deprivation or neither confined or deprived). Although our data indicate that relatively little serious anxiety developed during periods of deprivation up to 23 hours in length, there were too many differences in method, sex, sample, etc. to allow for meaningful comparisons with the Zuckerman,et al. study.

However, the present checklist data generally confirm our interview data, in that Ss reported feelings of anxiety but not serious disturbance. In order to investigate this question further, two subsamples were formed on the basis of their postisolation interview data: a group of Ss who reported that they felt "no anxiety" during any part of the experiment (N =10) and a group of Ss who reported that they felt "continuously anxious" during isolation (N=10). For the "no anxiety" group, 9 of the 10 Ss showed no serious disturbance on the checklist, while for the "continuously anxious" group, 5 of the 10 Ss indicated that they felt seriously disturbed during isolation.

There is a further point of interest concerning these two subgroups. Contrary to expectations, the "no anxiety" group spent less time in isolation (42.2 hrs.) than the "continuously anxious" group (60.1 hrs.). Additionally, only 3 of the 10 nonanxious Ss remained in isolation for 72 hrs. whereas 7 of the 10 anxious

Ss did so. Evidently, continued isolation generates feelings of anxiety; however, these feelings do not necessarily result in the decision to leave isolation.

4. Motor Variables

Two tests of motor functioning, described below, were introduced into the test battery. Their general purpose was to obtain measures of strength and coordination. Additionally, a measure of body movement during isolation was obtained.

Hand Strength

The Smedley Dynamometer was used to measure hand strength. The measure was taken while S was seated, with his arms at his sides. The following instructions were read:

"This instrument is for testing your strength, and, therefore, you must squeeze as hard as you can. With your arm down at your side, squeeze once as hard as possible."

S responded three times consecutively with one hand and then three times with the other. Order of hands tested was alternated with successive Ss.

Table 15 presents the mean change in hand strength after isolation for each group, and summarizes the results of the various t tests performed.

For the nonisolated hand (Table 15B), all groups showed nondifferential decrement in performance. The decrement was significant only in the 72-hr. group. On the isolated hand, however, (Table 15A), both Isolation groups showed significant decrement in hand strength. The postisolation performance of the $<$ 72-hr. group was significantly poorer than that of the Controls.

Table 15

Hand Strength

A. Isolated Hand (Nonpreferred)

Groups	N	M_d	t_d	t_c	t_e
Control	24	-0.42	0.50	-	-
72-hour	20	-2.71	3.14**	1.90	.76
< 72-hour	20	-3.95	2.83*	2.26*	

B. Nonisolated Hand (Preferred)

Groups	N	M_d	t_d	t_c	t_e
Control	24	-1.24	1.91	-	-
72-hour	20	-1.36	2.33*	.13	.03
< 72-hour	20	-1.32	1.19	.06	

Note. Mean cell entries are in kgm. See Table 8 for explanation of symbols.

* $p < .05$, ** $p < .01$

Vernon, et al. (1961) have reported that *Ss* wearing restrictive gloves for 24 or 48 hrs. showed a slight gain in hand strength, while *Ss* isolated for 72 hrs. showed a loss. Our results cannot be directly compared with those of Vernon, et al., since the isolating devices employed in the present study were more restrictive on the isolated hand, and less restrictive on the nonisolated hand than the gloves worn by their *Ss*. However, the present results do not seem to confirm the Vernon, et al. findings, in that decrement was shown by the < 72-hr. as well as by the 72-hr. groups.

Speed of Finger Oscillation

This test utilized the Weinstein Finger-Tachometer, which consists of two one-inch Teflon buttons, mounted on a smooth surface, and connected to individual mechanical counters. The counters register a count only when the button is fully depressed and released. Instructions to S were:

"Place both hands flat (palm down) with the tips of your index fingers above the white buttons. I am going to measure how fast you can tap these buttons with your index fingers for 10-second periods. You must leave your hands and all other fingers perfectly flat against the surface of the apparatus. Be sure to depress the button all the way and to lift the index finger off the buttons after each depression, otherwise the counter does not work. Tap as fast as you can. I will give you six trials, each ten seconds long."

There was no planned rest period between any of the trials, except for the time needed to record S's score, and to reset the counters (approximately three seconds). This test, therefore, was one of finger dexterity and fatigability. Table 16 presents the mean differences after isolation for all groups on this measure, and the t tests between groups.

Table 16

Speed of Finger Oscillation

A. Isolated Hand (Nonpreferred)

Groups	N	M_d	t_d	t_c	t_e
Control	23	-1.01	1.28	-	-
72-hour	22	-1.38	2.84*	.30	.16
< 72-hour	19	-1.18	1.67	.16	

B. Nonisolated Hand (Preferred)

Control	23	-1.27	1.62	-	-
72-hour	22	-1.15	1.90	.12	.07
< 72-hour	19	-1.23	1.32	.03	

Note. Mean cell entries are number of oscillations per 10-sec. period. See Table 8 for explanation of symbols.

* $p < .01$

The results indicate no impairment in speed of finger oscillation, which can be attributed to the effects of sensory deprivation. There are no previous reports on the effects of deprivation on any motor measures which are comparable to that of the present study.

Gross Bodily Movement

Observation* of S's bodily movement was made continuously during isolation via the closed-circuit TV system, and recording of activity on special forms was routine. While it was impossible for E to observe and record every movement (four Ss were simultaneously being monitored), excessive movement was recorded. The unit of excessive movement was defined as a period of 20 sec. of continuous movement, exclusive of purposive movements. Purposive movements were defined as drinking water or liquid diet, eating bread, and going to toilet. These times were also separately recorded. For each S the excessive movement units were summated for each six hour period spent in isolation.

Table 17 presents the results of the analysis of excessive gross bodily movement in terms of mean number of units per hour for the first six hours, the last six hours and for the total isolation period.

Table 17

Average Excessive Movement Units for Initial and Final Phases of Isolation

Group	N	Mean Hours in Isolation	Mean Number of Excessive Movement Units Per Hour		
			During Entire Period	During Initial 6 Hours	During Final 6 Hours
< 24 hrs.	8	12.6	.40	.12	.77
24-47 hrs.	6	27.7	.38	.11	.89
48-71 hrs.	8	55.5	.44	.23	.54
72 hrs.	22	72.0	.34	.09	.42

* A system of microswitches buried in each mattress designed for automatic recording of movement, proved to be unreliable for the present series of Ss.

During the first six hours of isolation there appears to have been little excessive movement in any group, with the 72-hr. Ss showing the least movement. However, all groups clearly demonstrated an increased number of movements during their final six hours in contrast with the initial six hours of isolation. The Ss showing the largest increase of movement were those who remained for 24-47 hrs.; they averaged an eightfold increase in the final period and showed greater movement during this period than any other group.

Our data are consistent with those of Smith, Myers, and Murphy (1962) which demonstrated a negative relationship between tolerance for isolation and frequency of movement. In their study, Ss who remained in isolation for long periods did not differ in frequency of movement from "early-release" Ss for the first day of isolation. However, during the second day of isolation the "long-staying" Ss showed a significantly smaller increase in frequency of movement than the "early-release" group.

5. Sensory Variables

The following series of tests were designed to obtain absolute (RL) and difference (DL) thresholds in the somesthetic, auditory, and visual modalities. In addition, thresholds for pain sensitivity and tolerance were obtained.

Somesthesis

Absolute Threshold for Pressure Sensitivity (RL). The threshold for punctate pressure stimuli was determined by means of the Semmes-Weinstein Esthesiometer, which consists of 20 nylon monofilaments, 28 mm. in length, ranging in diameter from .06 to 1.14 mm. Each filament is imbedded in one end of a plastic rod. The filaments were calibrated by means of a chemical balance which recorded the force required to bend them by pressing the tips against the pan.

The following instructions were read to S.

"We want to measure the minimum pressure you can feel. I will touch your palm with a series of nylon hairs; whenever you feel something, tell me so."

The blindfolded S placed his nonpreferred forearm and hand on a table padded with foam rubber. He was tested on the palm of the nonpreferred hand at the point at which an imaginary line drawn from a point midway between the middle and ring fingers perpendicularly intersects with one drawn from the point of intersection of the thumb with the palm. For the first trial, the starting stimulus was the filament with the least pressure.

Filaments of increasing pressure were successively applied for about one second, with three to eight seconds between contacts, until S reported a sensation. Starting at randomly varying levels below the previously determined threshold, the filaments were applied in sequence for a total of four ascending threshold determinations.

The results for absolute pressure sensitivity are shown in Table 18. The 72-hr. isolation group showed a significant decrement in postisolation sensitivity. The decrement was also significantly different from the Control and < 72-hr. groups.

Table 18

Threshold for Absolute Pressure Sensitivity (RL)

Groups	$\underline{N}$	$\underline{M}_d$	$\underline{t}_d$	$\underline{t}_c$	$\underline{t}_e$
Control	22	0.002	0.02	-	
72-hour	21	0.41	4.73***	3.28**	2.32*
< 72-hour	17	0.09	0.83	0.63	

Note. Mean cell entries are in log 0.1 mg. units. See Table 8 for explanation of symbols.

* $p < .05$, ** $p < .01$, *** $p < .001$

In an earlier study, Reitman and Cleveland (1964) found that for normal Ss four hours of sensory deprivation impaired pressure sensitivity on both the wrist and finger. Heron and Morrison (Morrison, 1962; Heron & Morrison, P. C.), however, have shown that isolating the skin alone can improve pressure sensitivity after 96 hours. This latter experiment was replicated in this laboratory and the results confirmed (c.f., p.6). In our hand-isolation experiment reported above (p.3), there was a nonsignificant tendency toward improved sensitivity after 96 hours. In the present study there was a significant decrement of palm sensitivity following 72 hours of sensory deprivation. It is possible that total sensory deprivation may impair sensitivity, while local isolation of skin may improve it. It is also possible that a "U-shaped" function exists in this area, with fairly short (< 72-hrs.) or sufficiently long (> 96-hrs.) periods of deprivation improving sensitivity, while a 72-hr. period leads to impairment. Additional research is necessary to help select the proper alternative.

Difference Thresholds for Pressure (DL). The apparatus for testing difference thresholds for pressure sensitivity consists of a series of 24 micro-Fernbach flasks, 5 ml. in capacity, weighted by gunshot and absorbent cotton. A smooth plastic disk, 26 mm. in diameter kept the bottom of all flasks identical in size. The standard flask weighs 30 gm. and the comparison flasks vary from 19 to 33 gm., in 1 gm. steps.

For each judgment, two stimulus objects, a standard and a comparison, were successively placed on S's nonpreferred palm, over the distal half of the fourth metacarpal bone. Each weight was left on the palm for 2 sec., with a 2 sec. interval between stimuli, and a 5 sec. interval separating judgments. S was required to judge whether the second weight was heavier or lighter than the first (no equal judgments were allowed). The first comparison stimulus of each series was started randomly at from 10 to 15 gm. below the standard and increased in 1 gm. steps for each succeeding judgment. The threshold was that point in the series at which S judged the variable weight to be heavier than the standard.

On succeeding trials the order of presentation of the two stimuli was reversed such that for half the trials the standard was presented first, and for the other half, the comparison first. Four threshold determinations were made for each S, with a 10 sec. interval between determinations.

Table 19 presents the mean differences after isolation for each group and the results of the t tests comparing subgroups.

Table 19

Difference Thresholds for Pressure Sensitivity (DL)

A. Average Deviation from Standard

Groups	N	M_d	t_d	t_c	t_e
Control	21	-.33	0.41		
72-hour	20	-.30	0.50	0.03	1.12
< 72-hour	19	-1.45	1.71	0.95	

B. Constant Deviation from Standard

Control	21	0.31	0.32		
72-hour	20	0.35	0.56	0.03	1.13
< 72-hour	19	1.55	1.78	0.95	

Note. Mean cell entries are in gms. See Table 8 for explanation of symbols.

In Table 19A, it can be seen that there is a general decrease in Average Deviation (AD) for all groups upon retesting. The greatest improvement in accuracy is shown by the < 72-hr. group, but this change is not statistically significant, nor are any of the group comparisons significant.

In terms of Constant Deviation (CD), all groups underestimated the standard before isolation. All groups showed decreased underestimation of the standard after isolation, but none of the decreases were significant, nor did any of the groups differ significantly from each other.

Previous studies of the effects of deprivation on tactual sensitivity have used two-point limens. Except for a study of four hours of isolation (Reitman and Cleveland, 1964) all studies have shown improvement in two-point sensitivity following deprivation. The most comprehensive study was that by Doane, et al. (1959) in which two-point discrimination was tested over four body parts following 48 and 72 hrs. of deprivation. They reported that proximal body parts tended to improve more than distal body parts, and that 48 hrs. tended to produce more of an improvement than 72 hrs. of deprivation. In the present study, the < 72-hr. group tended to show a greater decrease in AD than the 72-hr. group or the Controls. Thus, despite the difference in discrimination tests, the results tended to be consistent with those of Doane, et al., in demonstrating the greatest improvement for the < 72-hr. group and lesser improvement after 72 hrs. of isolation.

Audition

Auditory Test System. The auditory system consisted of an audio-oscillator, two audioswitches, and a power amplifier. The oscillator (ultrastable Waveforms Model 401 B) has a frequency stability of better than $\pm$ 0.5%. The audioswitches (Scientific Prototype) allow independent control over attack and decay times, without baseline distortion or envelope modulation. They are capable of attenuating the input signals in .1 db. steps over a range of 111 db., with an accuracy of 0.5%. The power amplifier was a dual input, single output unit with a power capability of 15 watts. This drove a pair of Koss Pro-4 wide-band stereo-earphones calibrated so that the sound pressure output for a given voltage input was known.

Ancillary monitoring equipment comprised an electronic counter and an AC voltmeter (Hewlett Packard Model 403B). The entire system was controlled by logic modules, which also served to control time and order sequencing of the visual stimulating system.

Absolute Loudness Thresholds (RL). Absolute loudness thresholds were determined as follows: S sat in the soundproofed test room where the following instructions were read to him:

"We are going to measure the minimum sound level you can hear. Every time you step down on this foot pedal, you are presenting yourself with a tone. Most of the time you will not hear this tone but when you do hear it, please press this telegraph key in front of you. Step down on the pedal every 5 seconds. Be sure you hear the tone before you respond."

S then put on the earphones and the stimulus tone was presented binaurally through the earphones for a duration of 250 msec. each time S depressed the pedal. The primary signal was at an intensity of 80 db. Variations in intensity were accomplished by varying the degree of attenuation. Four ascending series were given, starting well below threshold, at an attenuation of the primary signal of 100 db. For the first trial, the intensity of the stimulus was increased in 10 db. steps (by decreasing attentuation) until S reported hearing a tone. The attenuation was then increased by 10 db. and decreased in a series of 1 db. steps until S responded again. This response was taken as the threshold measure. The three succeeding trials were started 10 db. below the first threshold, increasing in intensity in 1 db. steps until S reported hearing a tone. "Catch trials" were randomly interspersed, and any responses noted.

Table 20 presents the mean differences in auditory RLs after isolation for each group and summarizes the results of the t tests. Both the Control and 72-hr. groups improved significantly in their loudness thresholds upon retesting.

Table 20

Thresholds for Absolute Loudness Sensitivity (RL)

Groups	N	M_d	t_d	t_c	t_e
Control	13	-1.96	3.57*	-	-
72-hour	16	-3.62	3.89*	1.45	1.55
< 72-hour	14	0.21	0.09	0.85	

Note. Mean cell entries are in db. See Table 8 for explanation of symbols.
* $p < .01$

Although the 72-hr. group improved somewhat more than the Control and < 72-hr. groups, these differences were not significant. The latter group actually had a nonsignificant decrement in sensitivity but did not differ from the Controls. Thus, three days of total sensory deprivation did not significantly change absolute auditory thresholds. In a previous study, Duda and Zubek (1965) also found no significant change in absolute auditory thresholds after seven days of visual deprivation.

Difference Thresholds for Loudness (DL). To test difference thresholds for loudness, two signals, a standard and a comparison tone, were each presented for 250 msec. durations at a frequency of 1,000 cps. with an interval of 500 msec. between stimuli. The standard stimulus was set at an attenuation of 40 db.; the comparison stimulus was started at an attenuation of 50 db., and was increased in 1 db. steps. The order of presentation for the standard (A) and the comparison (B) was ABBA. By means of two telegraph keys, S reported whether the second signal was louder or softer (no equal judgments allowed). The difference threshold was that point in the series at which S judged the comparison stimulus to be louder than the standard. Four such determinations were made.

The mean average deviation (AD) and mean constant deviation (CD) differences (post- minus preisolation score) for each group are presented in Table 21 with the results of the t tests.

Table 21

Difference Thresholds for Loudness (DL)

A. Average Deviation from Standard

Groups	N	M_d	t_d	t_c	t_e
Control	15	-.70	1.20	-	-
72-hour	16	-.34	1.12	0.56	1.74
< 72-hour	16	.89	1.40	1.84	

B. Constant Deviation from Standard

Control	15	.67	1.01	-	-
72-hour	16	-0.25	0.61	1.20	0.87
< 72-hour	16	-1.23	1.17	1.51	

Note. Mean cell entries are in db. See Table 8 for explanation of symbols.

For average deviation (AD) none of the groups changed significantly, nor were any of the group comparisons significant.

For constant deviation (CD), all groups showed an initial tendency to underestimate the loudness of the standard tone prior to isolation. In the second testing, the controls tended to show less underestimation, whereas the isolation groups increased the amount of underestimation, particularly the < 72-hr. group. However, none of the comparisons were stastically significant.

The results indicated, therefore, that auditory discrimination thresholds are not changed following three days of total sensory deprivation. Duda and Zubek (1965) reported that following seven days of darkness there was animprovement in auditory discrimination as measured by auditory flutter fusion technique.

There have also been several studies of the effects of deprivation on auditory vigilance. Myers, et al. (undated) reported an improvement in auditory vigilance following 72 hrs. of sensory deprivation when compared to controls tested in the dark, and no difference when compared to controls tested in the light. Zubek, et al.

(1961) found no difference following seven days of sensory deprivation. In a later study, Zubek,et al. (1962) found an impairment in auditory vigilance following seven days of perceptual deprivation. In view of the employment of different techniques, however, the results are not directly comparable to those of the present study.

Vision

Visual System. The basic unit of the visual testing system was a six- channel Dodge-type tachistoscope (developed for this laboratory by Scientific Prototype) using transilluminated stimuli. The light sources are lamps producing white light of constant intensity for a constant current. The rise time of the entire system, from onset of control signal to full lamp intensity output is 25 μsec.

The visual tests were controlled by time-interval generators whose outputs are variable from 100 μsec. to 110 sec. with an accuracy and repeatability of 2%.

Threshold for Absolute Brightness Sensitivity (RL). *S* was tested after from 30-60 min. of dark adaptation. *S* was seated in the soundproofed test room and wore an earphone for communication with *E*. *S* looked with his right eye into the eyepiece of the tachistoscope. (The stool height and eyepiece had been previously adjusted). The following instructions were then read:

> "We are going to measure the minimum amount of light you can see. Put this foot pedal near your preferred foot; step down on the pedal. Every time you do so, you are presenting yourself with a flash of light. Most of the time you will not see this flash of light, but when you do see it, please press this telegraph key in front of you. Step on the pedal about every five seconds. When the door is closed and the lights are turned off, I will let you know so that you can take off your blindfold and look into the eyepiece with your right eye. You must see a circle. If you don't,look around in the eyepiece for it. Look straight at the line on the circle, which is located on the left side of the circle at 9 o'clock. Never look directly at the center of the circle where a dot of light will appear; otherwise you will not see it."

The fixation stimulus consisted of a 4.5° circle which is barely perceptible to the dark-adapted eye at the minimum brightness setting of the tachistoscope. The stimulus for determination of the brightness threshold consisted of a point of light of constant brightness in the center of the opaque field. This stimulus was varied in duration; the light from the increasing durations was integrated by S and perceived as increasing brightness at the brief intervals utilized. This method avoids the problem of color changes which occur with increasing intensity. It also permits more precise and reliable control over stimulus parameters than is presently possible with direct intensity variation.

Four ascending trials were presented. The first trial was administered as follows: after S indicated he was ready to receive a signal, a flash of light 1.1 msec. in duration was presented. The light illuminating the fixation circle was extinguished whenever the visual stimulus appeared and was turned on at the termination of the stimulus. The fixation circle, however, appeared to be present at all times. If no detection response was given, the duration of the stimulus was increased in .5 msec. steps for each succeeding stimulus until S responded that he had detected the light. E then reduced the flash duration by .5 msec. and the stimulation duration was increased in steps of .1 msec. until S responded again. This second response constituted S's threshold for the trial. For trials 2, 3, and 4, the starting point was from .5 to .9 msec. below S's previous threshold, with steps of .1 msec. until S responded.

Table 22 presents the mean differences after isolation for each group and results of the various analyses. None of the groups demonstrated significant changes, nor were there significant differences between the groups for absolute brightness thresholds after isolation.

These results conform to those of previous studies, which, despite utilization of different techniques, also indicated no significant changes following deprivation (Doane, et al., 1959; Batten, 1962).

Table 22

Thresholds for Absolute Brightness Sensitivity (RL)

Groups	N	M_d	t_d	t_c	t_e
Control	13	0.12	0.60		
72-hour	12	0.58	1.82	1.23	1.05
< 72-hour	13	0.07	0.19	0.12	

Note. Mean cell entries are in msec. See Table 8 for explanation of symbols.

Difference Thresholds for Brightness (DL). This test was conducted immediately after the determination of visual RL. The tachistoscope, logic system, and stimuli are described above.

Two points of light were presented successively at differing durations. Despite the identical brightnesses S perceived the two points as differing, not in duration, but rather in brightness. The following instructions were read to S:

"Everytime you step down on this pedal with your preferred foot, you will see two flashes of light. If you judge that the second flash is dimmer than the first, press the left telegraph key; if you think that the second flash is brighter than the first, press the right telegraph key. You must give a response, even if you are not sure. No equal judgments are allowed. Step down on the pedal about every 5 seconds. When you look into this eyepiece you must see a circle. Look at the line which is located on the left side of the circle at 9 o'clock. The dots will appear at the center of the circle but you must not look at them directly, always look directly at the line."

The threshold was based upon four trials. In trials 1 and 4 the standard stimulus appeared first; in trials 2 and 3, the comparison stimulus appeared first. There was an interval of 500 msec. between stimuli. For the first trial, the standard stimulus was set at 8 msec. The comparison stimulus was started at 3 msec. and was increased in .5 msec. steps until S reported the comparison as "brighter." This duration of the comparison stimulus was taken as the threshold for the trial. In the three succeeding trials, the comparison stimulus was started at from 1.5 to 2.5 msec. below the preceding threshold and again increased in .5 msec. steps until S reported the comparison stimulus as brighter.

Table 23 presents the differences after isolation and the results of the t tests for the various groups.

There were neither significant changes in average or constant deviation following isolation in any group nor were there any significant differences between the groups for these measures.

Zubek (1964b) similarly had found that seven days of perceptual deprivation produced no change in brightness discrimination.

Table 23

Difference Thresholds for Brightness (DL)

A. Average Deviation from Standard

Groups	N	M_d	t_d	t_c	t_e
Control	13	0.32	1.29	-	-
72-hour	11	-.16	0.34	0.96	0.82
< 72-hour	13	0.31	0.86	0.02	

B. Constant Deviation from Standard

Groups	N	M_d	t_d	t_c	t_e
Control	13	-.53	1.65	-	-
72-hour	11	0.41	0.82	1.64	1.04
< 72-hour	13	-.32	0.66	0.36	

Note. Mean cell entries are in msec. See Table 8 for explanation of symbols.

Pain Testing

A modified cold pressor method was employed for pain testing. There were two measures obtained from this test: pain threshold and pain tolerance. The measures were obtained for each hand individually. The apparatus consisted of a tank of water at 0° C. A pump at the bottom of the tank kept the water-ice mixture circulating so that a heat gradient would not develop around the immersed hand. In order to keep depth of immersion constant from pre- to postisolation testing, an ink mark was placed at the styloid process of the ulna. Testing order of the preferred and nonpreferred hands alternated with successive Ss.

S was instructed as follows:

"Place your hand in the water up to the wrist. As soon as it becomes painful, tell me, but do not remove your hand until the pain becomes intolerable. Keep your hand relaxed but do not move it in the water."

Pain threshold was the time in seconds from immersion of the hand until S reported pain. Pain tolerance was the number of seconds from immersion of the hand until S reported that the pain was intolerable. If no such report was made at the end of three minutes, the trial was terminated.

Pain Threshold. The mean difference after isolation for each group as well as the results of the t tests are shown in Table 24.

Table 24

Pain Threshold

A. Isolated (Nonpreferred) Hand

Groups	N	M_d	t_d	t_c	t_e
Control	19	-3.60	2.21*	-	-
72-hour	21	-7.56	1.28	0.62	0.42
< 72-hour	22	-5.06	3.18**	0.64	

B. Nonisolated (Preferred) Hand

Control	19	-2.95	2.89**	-	-
72-hour	21	-6.63	0.70	0.37	0.02
< 72-hour	22	-6.39	2.04	0.98	

Note. Mean cell entries are in sec. See Table 8 for explanation of symbols.
* $p < .05$, ** $p < .01$

All groups showed a decrease in pain threshold on both hands. This decrease was significant for both hands in the Control group, and for the nonisolated hand for the < 72-hour group. Since none of the groups differed significantly on either hand for this variable it can therefore be concluded that there is no apparent effect of sensory deprivation on pain sensitivity.

A lowering of pain thresholds following various forms of deprivation was found in several previous studies (Vernon & McGill, 1961; Zubek, Flye, & Willows, 1964; Zubek, Flye & Aftanas, 1964). Body immobilization alone produced no significant change (Zubek, Aftanas, et al., 1963; Zubek & Wilgosh, 1963).

With total perceptual deprivation, Zubek, et al. (1962) found a raised threshold for pain; however, the authors attributed this to the analgesic properties of the white noise.

Pain Tolerance. Table 25 presents the mean difference after isolation for each group as well as the results of the t tests for the pain tolerance measure.

Table 25

Pain Tolerance

A: Isolated (Nonpreferred) Hand

Groups	N	M_d	t_d	t_c	t_e
Control	20	-11.10	0.84	-	-
72-hour	21	-10.57	1.00	0.03	0.86
< 72-hour	21	-24.38	2.04	0.75	

B: Nonisolated (Preferred) Hand

Groups	N	M_d	t_d	t_c	t_e
Control	20	-7.37	0.63	-	-
72-hour	21	-14.86	2.58*	0.58	0.52
< 72-hour	21	-21.80	1.79	0.86	

Note. Mean cell entries are in sec. See Table 8 for explanation of symbols.

* $p < .05$

For both the isolated and nonisolated hands, all groups showed a decrease in tolerance on posttesting, but the only statistically significant change was for the 72-hr. group on the nonisolated hand. None of the group comparisons were significant. It seems, therefore, that changes seen after isolation are quite similar for pain threshold and pain tolerance.

Summary and Comment: Sensory Deprivation Studies

The effects of varying periods of total sensory deprivation were studied in Ss who entered deprivation chambers planning to remain for 72 hours. The dependent variables were a variety of absolute and difference sensory thresholds, and various cognitive, motor, and physiological measures.

This section presents a brief summary of the significant effects of sensory deprivation obtained in the present studies, and some conclusions which follow therefrom.

Local Isolation of Skin.

1. Hand isolation produced a transient improvement for point localization. None of the other sensory measures were affected by isolation.

2. Isolation of a region of the forearm produced a significant improvement of pressure sensitivity compared with the contralateral homologous and non-homologous areas.

Total Sensory Deprivation.

1. Inability to remain in isolation for 72 hours was shown by 53% of the Ss. This figure is equivalent to that of Myers' study (52%), but somewhat higher than the rates reported by Zubek (32%) or Vernon (32%).

2. The times at which Ss chose to leave isolation seemed to follow a circadian rhythm, with peaks occurring approximately every 24 hours.

3. The postisolation interview revealed the following:

a. 80% felt anxiety at some time during isolation.

b. There was little evidence of claustrophobia.

c. A majority of Ss would have preferred different food.

d. Almost all Ss complained of the discomfort caused by the experimental equipment during isolation. However, almost none complained of being continuously monitored.

e. Although most Ss found the specific physical arrangements of the experiment uncomfortable, e.g., monotonous diet, cramped quarters, restricting equipment, nevertheless, these factors did not differentially influence those Ss who remained or failed to remain in isolation.

f. Most Ss slept as long as possible and dreamt pleasant dreams, most of which were in color.

g. About half the Ss had difficulty in thinking; 84% daydreamed.

h. Most (90%) had trouble keeping track of time, and 85% of them were disturbed by this failure.

i. Almost all (95%) had no trouble spatially orienting themselves to their cubicle.

j. 82% reported bodily discomfort; 31% were bothered by darkness, boredom, or both.

k. Visual sensations of varying intensity and complexity were reported by 41% of the Ss; only 5% reported auditory hallucinations.

l. 40% reported willingness to serve as Ss at some future time.

4. The following results were obtained from the physiological variables.

a. GSR recording showed a generally declining basal skin-resistance during isolation.

b. Correlations (r) of GSR with total isolation time and calendar time in isolation were -.32 and -.77 respectively. Partialling out ambient temperature, the r between GSR and calendar time remained -.66 ($p < .01$).

c. EEG frequency spectra were computed for individual Ss for each hour of isolation. Quite reliable individual differences in frequency spectra were obtained as a function of isolation. Thus, one S showed a negative correlation (-.85) between percentage occurrence of beta activity as a function of time in isolation and positive correlations for alpha, theta, and delta activity (.59, .47, and .58 respectively). The converse, i.e., positive correlation for beta, and negative for alpha, theta, and delta, was shown by another S.

d. Metabolic variables were also studied, i.e., bread, liquid diet, and water intake, body weight, and weight of excreta. Ss 72 hours in isolation lost significantly more weight than Ss < 72 hours in isolation. Both isolation groups lost significantly more weight than nonisolated controls. Interestingly, the group remaining in isolation for a mean of 55.5 hours ate only slightly less bread, drank slightly less water and drank the same amount of liquid diet as the 72-hour Ss. They also lost more weight than these Ss despite spending 15.5 hours less in isolation.

5. The cognitive variables comprised three subtests of the Employee Aptitude Survey (EAS), a time-estimation test, and an adjective checklist.

a. Verbal comprehension was unimpaired following isolation.

b. Visual pursuit was relatively unimpaired by isolation. However, the group remaining in isolation 72 hours showed some tendency toward impairment on this measure.

c. The entire isolation group showed a tendency toward impairment on space visualization.

d. The Ss remaining in isolation < 72 hours changed significantly from overestimation of the 10-second period before isolation to underestimation after isolation.

e. Disturbance, as indicated by the adjective checklist, was not shown by many Ss after isolation. The fact that only few of the early-release Ss reported disturbance indicates that leaving isolation early was not a function of degree of disturbance.

6. The motor variables consisted of: hand strength, speed of finger oscillation, and gross bodily movement.

a. For the Isolation groups, the isolated hand was significantly weaker after isolation and the < 72-hour Ss differed significantly from the controls. On the relatively nonisolated hand, only the 72-hour group was significantly weaker after isolation.

b. Rapid finger oscillation was significantly impaired after isolation for the isolated hand of the 72-hour group.

c. Excessive gross bodily movement during isolation increased two- to threefold during the final six hours in contrast to the first six hour period the Ss remained in isolation. Ss remaining in isolation from 24-47 hours showed the greatest increase in excessive movement in their final six hours as compared with any other "early-release" subgroup or 72-hour Ss.

7. The sensory variables comprised absolute (RL) and difference limens (DL) for somesthesis, audition and vision. Pain sensitivity and tolerance were also studied.

a. Absolute pressure sensitivity on the palm showed a decrement for the 72-hour group.

b. For difference limens for pressure, there was a tendency for the < 72-hour Ss to show decreased average and constant deviations (AD and CD) after isolation.

c. Absolute loudness thresholds decreased significantly for the 72-hour and the Control Ss; however, the groups did not differ significantly from each other.

d. Difference thresholds for loudness did not change after isolation.

e. Neither RLs nor DLs (AD or CD) for brightness changed significantly after isolation.

f. All groups showed a decline in pain threshold and tolerance on both the isolated and nonisolated hands. However, there were no significant differences between the Isolation and Control groups.

Comment

The finding that limited isolation of hand or forearm resulted in enhanced tactual sensitivity of the isolated parts, and that total sensory isolation produced the opposite effect is paradoxical. It may be obvious to state that heteromodal effects apparently are operating to the detriment of somesthetic functioning when isolation is total. Another alternative concerns the possible role of activation or général vigilance which may be uninfluenced in specific deprivation and profoundly impaired when subjects are in total sensory isolation.

The less than dramatic failure to find full-blown hallucinations and disorientation appears all the more surprising in view of the generally higher proportion of early release requested by the volunteers in this study in contrast to earlier ones. It is quite conceivable that the complex tactual, visual, and auditory isolation contrivances, the relatively bland food, and the various electrodes attached to S increased their discomfort over that of earlier studies. The factors which produced greater discomfort and thus earlier release, may have resulted in a hidden benefit for the Ss: the increased concentration from preoccupation with lowered levels of comfort may concomitantly have produced increased activation, offsetting the anticipated more bizarre reactions (hallucinations, disorientation, paranoid attitudes, etc.) However, our Ss were not entirely free of "mental" problems; most daydreamed, dreamt in color, had difficulty keeping track of time and were thereby troubled, and had difficulty in thinking coherently.

Possibly the unusually extreme form of isolation we employed (e.g., not a word was exchanged, nothing sighted or heard, nor the cubicle left during isolation) was sufficiently effective in disturbing thought processes. Their constant preoccupation with comfort, on the other hand, may have protected them from further deterioration into the more extreme forms mentioned above. However, it must be pointed out that these interpretations are merely conjectural at this stage.

The generally declining basal GSR with isolation indicates an increased level of activation or arousal which conforms to the decreasing alpha and increasing beta activity of some Ss. However, paradoxically, another S showed the converse relationship between EEG frequency and time in isolation. It therefore seems to indicate the advisability of assessing the relationship between EEG and GSR with behavioral (and even subjective) effects of isolation. More sensitive indices of spatial orientation may also demonstrate impairments which grosser measures have not detected.

An unusual finding which may bear further exploration is the metabolic nonequivalence of the Ss remaining for the entire 72 hours of isolation and certain subgroups of the early-release Ss. One of latter groups, despite almost a full day less of isolation, ate and drank only slightly less, and lost more weight than the full-term isolation Ss. Possibly the same metabolic factors which enhanced their food intake and weight loss resulted in decreased ability to tolerate isolation. Moreover, the subgroups which remained in isolation less than 48 hours appear to be unusual in another respect which may have some basis in a different metabolic rate. Thus, their rate of excessive movement during their final six hours in isolation was nearly double that of the 72-hour Ss. It is premature to speculate whether the excessive movement precipitated the desire to leave isolation, whether an increased metabolic rate was responsible for the movement, or whether some (emotional) subjective factor preceded both.

The generally unimpaired sensory functioning of Ss after isolation was somewhat unexpected. It is possible that the conjectures concerning the dearth of bizarre reactions may likewise prove relevant here. In any event, the anticipated relationship between impairment of basic sensation and more complex behavioral impairments was not found. Possibly it is the correlative or the executive functions which are more impaired by deprivation than the basic sensory inputs.

Another alternative worthy of consideration is that perceptual, rather than sensory deprivation may result in basic sensory deterioration. It is a frequent finding in the neurological literature that total destruction of a sensory system (e.g., hemianopsia) may prove to be much less impairing to a patient than partial destruction, (e.g., hemiamblyopia). The interpretation of such a finding appears to be that when one utilizes a disordered input channel, the misinformation it yields may be more detrimental than total absence of information. In the latter case, one learns to depend upon alternative sources of information as replacements for the missing channels. The analogy to sensory and perceptual deprivation may prove worthy of investigation.

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