NASA CR 111866

A STUDY OF HUMAN PERFORMANCE IN A ROTATING ENVIRONMENT

by

J. A. Green, J. L. Peacock, A. P. Holm

SD 70-456

Research Conducted Under Contract No. NAS1-9711
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ACKNOWLEDGEMENTS

This program was conducted by the Life Sciences personnel of the Department of Flight Technology, Research, Engineering, and Test, Space Division, North American Rockwell Corporation, Downey, California. The technical assistance of Messrs. R.E. Rogoff, E.J. Byrne, W.H. Gardner, C.L. Longuiel, L.J. Raggio, and Mrs. B.B. Esch is gratefully acknowledged. The administrative assistance of Dr. J.G. Wells, Messrs. E.W. Johnston, D.J. Gildea, W.R. Rhote, N.F. Jacobson, and D. Taravella contributed directly to the success of the total program. The test subjects, Messrs. D.L. Hardin, W.G. Patton, D.E. Groves, H.C. Peregrine, R. L. Tillis, W.F. Fleming, and P.O. Harwell, who demonstrated enthusiasm, motivation, and cooperation, are worthy of commendation. The assistance of Dr. A. Graybiel and his staff of the Naval Aerospace Medical Research Laboratory in the subject selection and calibration was especially valuable in the design of the test program and validation of test results. Finally, the technical assistance and guidance of the NASA-LaRC technical representatives, Mr. W.M. Piland, and subsequently, Dr. H.G. Hausch, during the planning and conduct of this program has been greatly appreciated.

ABSTRACT

Provision of an artificial-gravity environment has been proposed for future space vehicles of the station/base class for the effectiveness, comfort, and convenience of the crew. Lack of sufficient data relative to the response of man to the attendant oculovestibular stimulations induced by multi-directional movement of an individual within the rotating environment to provide the required design criteria served as the rationale for this study. The evaluations performed in this study were not designed to resolve the questions relative to the advantages or disadvantages of weightlessness over artificial gravity, but rather to determine the overall impact of artificial-gravity simulations on potential design configurations and crew operational procedures. Gross locomotion and fine motor performance were evaluated on the NR-SD Rotational Test Facility at rotational rates of 3, 4, and 5 rpm, at selected radii between 0 and 78 feet. The test series consisted of 12 one-day, 1 three-day, and 1 seven-day test. Results of these evaluations indicate that crew orientation, rotational rates, vehicle design configurations, and operational procedures may be used to reduce the severity of the adverse effects of the Coriolis and cross-coupled angular accelerations acting on masses moving within a rotating environment. Results further indicate that crew selection, motivation, and short-term exposures to the rotating environment may be important considerations for future crew indoctrination and training programs.

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INTRODUCTION

NASA and North American Rockwell's Space Division are currently involved in a cooperative activity to define requirements and limitations for post-Apollo space vehicles. One such vehicle, the space base, will have the primary function of serving as a laboratory in which research can be conducted in disciplines such as physics, astronomy, biotechnology, advanced spacecraft technology, and earth resources. Since it is desirable to provide the scientist-astronaut with a more earthlike habitable environment, an artificial-gravity environment for the living quarters within the space vehicle is being considered in certain of the design configurations.

Space flights to date have not substantiated whether the use of artificial gravity is pertinent to the success of future space missions. That requirement will be determined only after longer-duration missions have been undertaken in weightlessness. However, since artificial gravity may enhance crew performance and mission success, it is important to understand the effects of rotation on man. Consequently, a thorough knowledge and technological base relative to the impact of artificial gravity on spacecraft design must be obtained through simulation and testing. Thus mission planning and spacecraft development will not be delayed because of a lack of adequate design criteria.

Habitability may be defined as those conditions and crew provisions that make life comfortable and enjoyable for off-duty personnel during an operational mission. Establishment of these standards, while not subject to classical experimental evaluations, must be pursued from both the analytical and subjective approach. These approaches require a critical analysis of the effects of the peculiar environment, as compared to the acceptable aspects of everyday living. In the artificial-gravity environment, crew responses to Coriolis forces, cross-coupled angular accelerations, gravity gradients, variations in traction, rates of adaption, and the susceptibility of the individuals to these oculovestibular stimuli will determine, in part, the acceptability or inadequacy of the habitability aspects of the space vehicle.

Advantages and disadvantages of artificial gravity versus weightlessness have been argued during the past few years. One group contends that the advantages of weightlessness far outweigh the disadvantages of restraint systems, lack of postural stability, and other manipulative problems associated with crew activities in the weightless environment. Space flights to date have demonstrated that crew performance and/or physiological status have been degraded insignificantly with respect to overall mission success in exposures up to 14 days. While reports of space sickness in response to the weightlessness were reported early by the USSR cosmonauts (ref. 1 and 2), space flights in the American Gemini program seemed to indicate that this would not be a problem. Subsequently, it has been found in several of the Apollo flights that crew motion during weightlessness can indeed induce a high level of motion sickness in the susceptible individuals (ref. 3 and 4). These manifestions of motion sickness may be reduced significantly by adequate indoctrinations and habituations.

A number of tradeoff studies relative to subsystem design for operations within the artificial-gravity versus weightless mode have indicated that gas-liquid separations, fluid flow, open container manipulation, etc., may be all enhanced by the presence of a gravity field, whereas centrifugation, forced flow, closed containers, etc. are required to accomplish the same operations in the weightless environment. Modification of certain hardware and subsystems for operation in the weightless environment may possibly result in increasingly complex design and operational procedures, at significantly higher costs. In contrast, it has been proposed that the presence of an artificial-gravity environment may enhance the crew members' ability to perform many other complex functions such as locomotion, cargo handling, food preparation, experiment manipulation, equipment maintenance and repair, utilizing simple reflex actions, thereby reducing the overall training requirements (ref. 5). It is recognized that space crews accommodate to the conditions of weightlessness quite rapidly, accomplishing rather complex tasks without conscious anticipation. Nevertheless, on the basis of the aforementioned rationale, the statement of work for the space station/base study specified (ref. 6):

> "Space Base will provide artificial g and zero g environments in separate volumes simultaneously. For example, the principal living quarters, command and control stations, and some laboratory space may be located in the rotating arm for the effectiveness, comfort, and convenience of the crew."

> "Acceleration levels in the main operating and habitability volumes will be between .3 and .7 times gravity. The nominal rotational rate will be 4 rpm."

Experience in other laboratories as well as on the Space Division's Rotational Test Facility (RTF) has shown that the movement of man within a rotating environment gives rise to bizarre stimulations of the vestibular, visual, and proprioceptor systems. The interaction of the environmental stimuli on these sensory systems may produce symptoms of vertigo, disorientation, lassitude, postural aberrations, or perhaps, ultimately, nausea, variously described as motion sickness, space sickness, or canal sickness (ref. 7 and 8). It has been demonstrated that many test personnel subjected to rotation in the Pensacola Slow Rotation Room respond with a deteriorization in well-being, frequently associated with a feeling of increasing lethargy. The turning or nodding of the head in a rotating environment generates cross-coupled angular accelerations that induce motion of the fluid within the semicircular canals not normally stimulated by such head movements in a stationary environment. This results in illusionary sensations of bodily or environmental motion (ref. 9 and 10). The intensity and duration of the symptoms appear to be related to the tolerance threshold of individuals to the vestibular stimuli. In addition to the non-normal stimulation of the semicircular canals, the otolith organs are subject to linear movement within the rotating environment (fig. 1). The magnitude of the Coriolis forces in the rotational environment is directly related to the angular velocity of the vehicle and the rate of linear motion of the individual or mass, either radially or tangentially, within the environment. Linear axial motion (i. e., locomotion parallel to the axis of rotation) does not produce Coriolis forces or other disturbing stimuli (ref. 11 and 12). The relationship of rotational rate, radius, and the artificial-g force is presented in figure 2. Figure 3 depicts the resultant g forces that are induced by the rotation of a vehicle. The linear velocity of an individual or mass located at a particular radius in a rotating environment is presented in figure 4.

The vestibular stimulations produced within the rotating environment may also give rise to visual illusions, such as the oculogravic illusion of an apparent tilt of the floor, when looking into or away from the direction of rotation, or an oculogyral illusion, such as the apparent movement of stationary objects when the head is rotated. Most individuals have experienced oculovestibular illusions, especially oculogyral sensations generated by rotating the body for several turns, then stopping. This results in an apparent rotation of the surroundings. Oculogravic illusions may have been observed as a tilt or "ramp" effect of the floor during takeoff and acceleration in commercial jet aircraft. It has been predicted that the maximum stresses in the rotating vehicle will be encountered by individuals moving radially between areas of high-gravity forces and low g or weightlessness, and back again, such as would be encountered in moving from the living area of the space base to the weightlessness laboratory and back. The severity of these stresses will impact the comfort and, consequently, the operational performance of the crew. Relatively few actual data exist with respect to the tolerance of man to repeated radial transfers within the rotating environment at long radii. It has been hypothesized that the magnitude of all stresses generated by movement within such an environment may be minimized through the techniques of configuration design, crew operation procedures, and crew selection and indoctrination. Hypothetically, the configuration of all equipment and aisles in an axial arrangement should reduce the number of crew motions that result in adverse effects (ref. 11). However, since the relegation of activities to eliminate all stressful stimuli is not practical, regardless of configuration, the determination of the optimum design, development of crew operational procedures, and

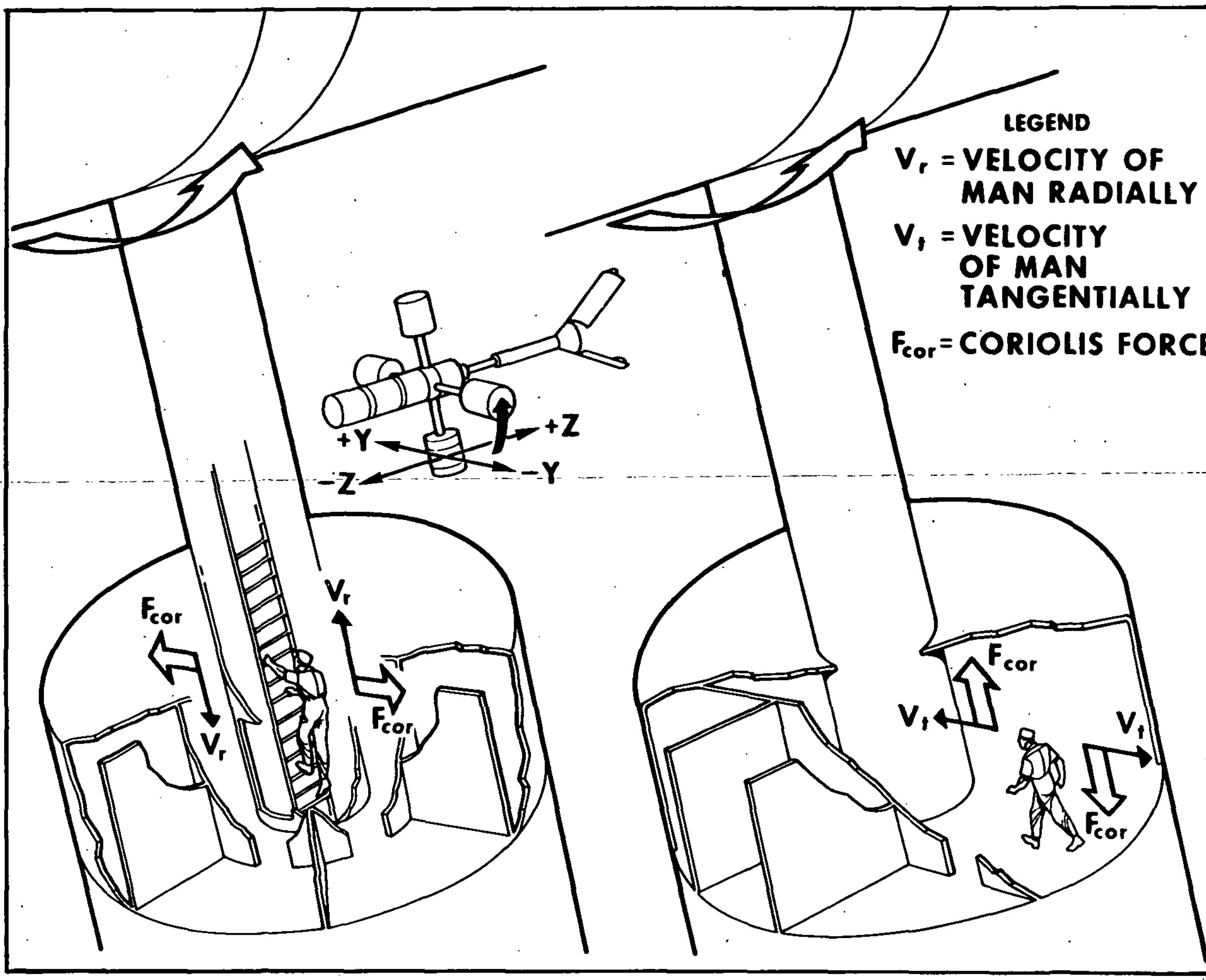

Figure 1. Inertial Forces in a Rotating Environment

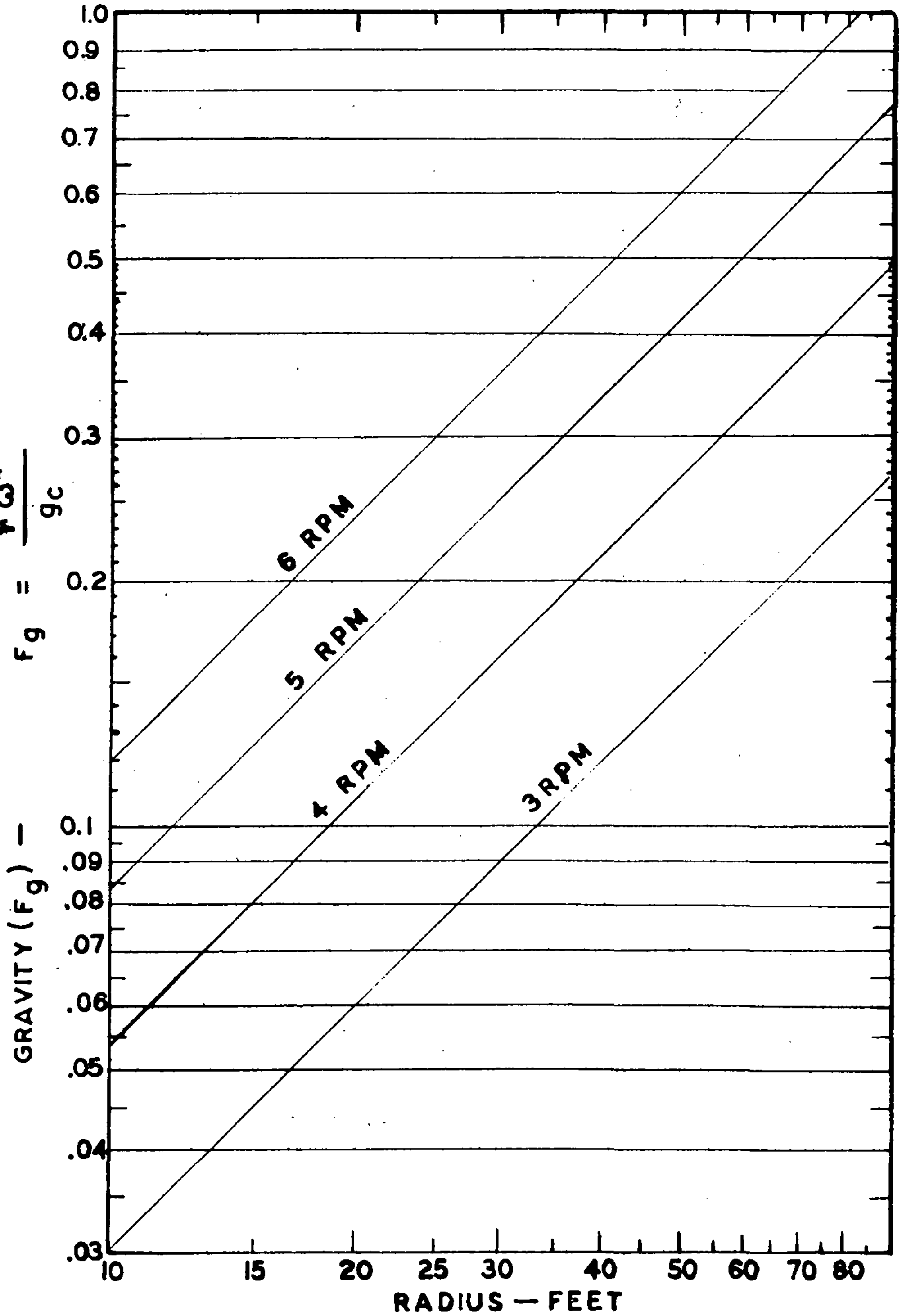

Figure 2. Artificial Gravity Vector

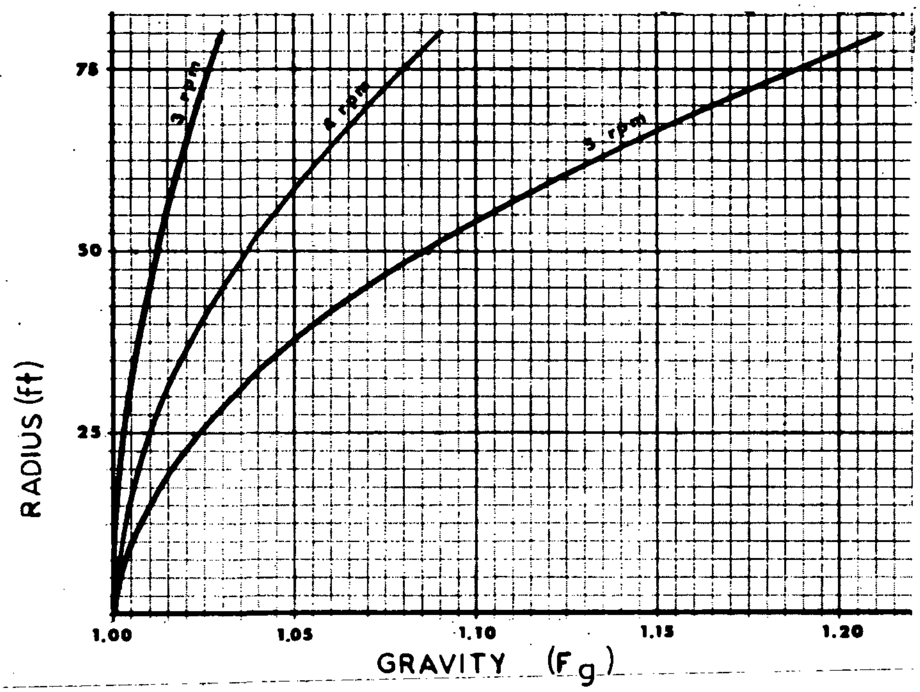

Figure 3. Resultant Gravity Vector

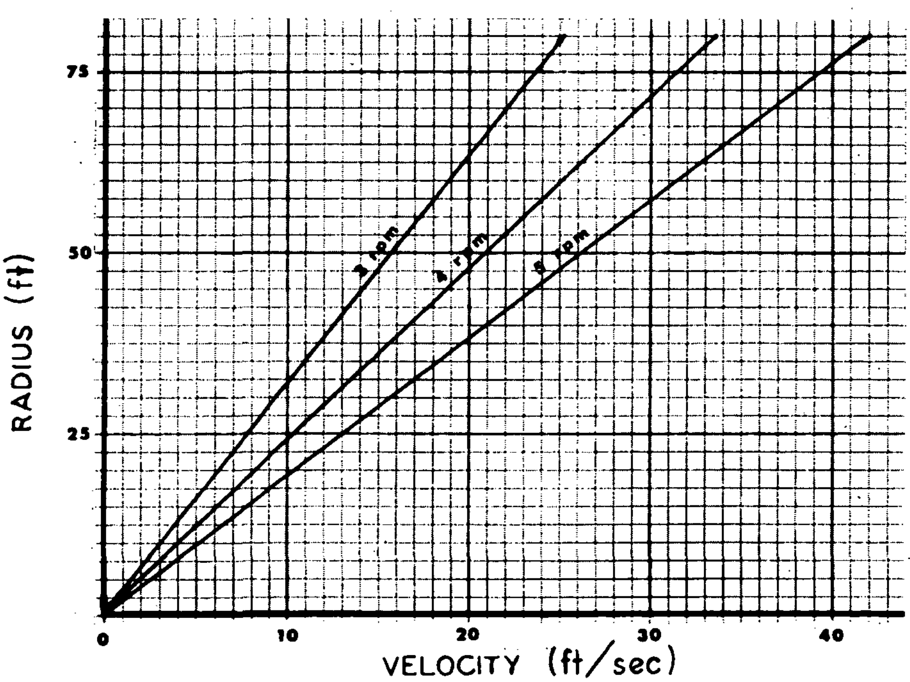

Figure 4. Linear Velocity on Rotational Test Facility

a better comprehension of the impact of the rotational environment on crew performance must be established through a program of test and evaluation.

The general objectives of research programs in the rotating environment is the acquisition of human performance data that may be used in development of space-vehicle design criteria. These data have particular significance and application to the design of rotating manned space vehicles and to the requirements for selection and training of crews for the operation of such systems. The test series in this initial program is designed to contribute data relative to that goal. The specific objectives of this test program are:

1. To evaluate the differential effects of crew movement and the attendant cross-coupled angular accelerations and Coriolis forces on psychomotor performance during exposure to varying rates of rotation, distances from the axis of rotation, and body orientations in the rotating system.

2. To evaluate the effects of the environment on psychomotor performance following transitions from the rotating to the nonrotating portion of the system, following different rates of rotation.

3. To evaluate the effects of the Coriolis forces generated during tangential and radial locomotion, and cargo handling at varying combinations of rotation rate, radius, and body orientation in the rotating system.

4. To evaluate the course of adaptation (as reflected in selected performance measurements) to the stimuli produced by periodic, short-term (one-day), and continuous (three- and seven-day) exposures to the conditions of the rotating environment.

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SECTION I
FACILITIES AND EQUIPMENT

The tests and evaluations described herein were conducted at North American Rockwell's Space Division (NR-SD) in Downey, California. The activities associated with subject selection, evaluation, and training were accomplished in the Life Sciences laboratories, which are equipped with a Cambridge pulmonary function tester, treadmills, bicycle ergometers, Benedict-Roth-type respirometers, Reikart ventilograph, tilt table, Beckman gas analyses equipment, and Sanborn Model 568 electronic recording equipment. A chemical laboratory is available for partial analyses of blood and urine. Training and testing rooms are used for the administration of psychological tests, interviews, briefing-debriefing, and psychomotor training.

The artificial-gravity tests were conducted on the NR-SD Rotational Test Facility (RTF) at rotational rates of 3, 4, and 5 rpm. This facility (fig. 5) is composed of a block-house control center, the drive hub, and the 160-foot-long rotating beam. The beam is 80 inches wide and protected along its full length by 7-foot walls on both sides. The crew module is located on one end of the beam at a mean radius of 75 feet. The internal dimensions of the module are 10 feet by 40 feet long. The floor of the crew module is automatically canted during rotation, to provide a walking surface normal to the total gravity vector. The module is equipped with a quick-opening hatch and an automatic adjusting stairway to permit ingress and egress while the facility is in motion. The module is equipped with four bunks, a head, shower, lavatory, kitchen-recreation area, and a psychomotor test area (fig. 6). Provisions for sewage and storage of potable water are adequate for the continuous testing with a crew of four men for 30 days. A 60-inch hollow bearing at the hub permits ingress and egress to the facility at all times. A special motionless test station, referred to as the hub station, has been constructed above the access way (fig. 7). On the module end of the beam are an overhead trolley system located 20 feet above the surface of the beam, and two ladders spaced 30 inches apart and extending from approximately 10 feet to a radius of 65 feet. A chain-driven cart controlled by a hydraulic motor has been installed between the ladders. It is adjustable for speeds up to 8 feet per second. A carpeted walk-way is located outside of the ladders on the leading edge of the beam (fig. 8). A special walk-around was constructed at the hub area to reduce interference with the test subject working in the hub station.

On the opposite end of the beam is located the counterbalance system. It is composed of large steel plates for gross weight control and an adjustable

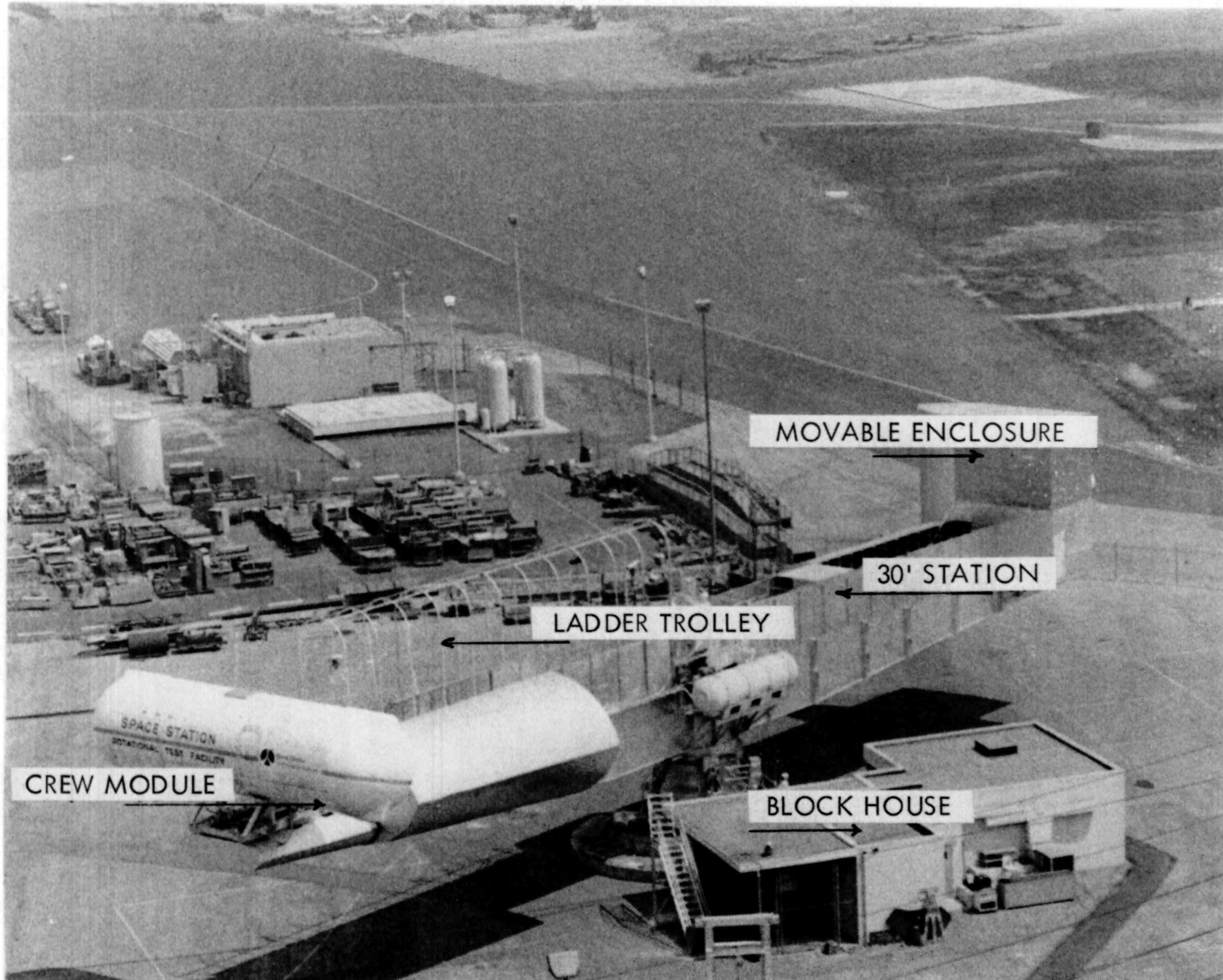

Figure 5. Rotational Test Facility

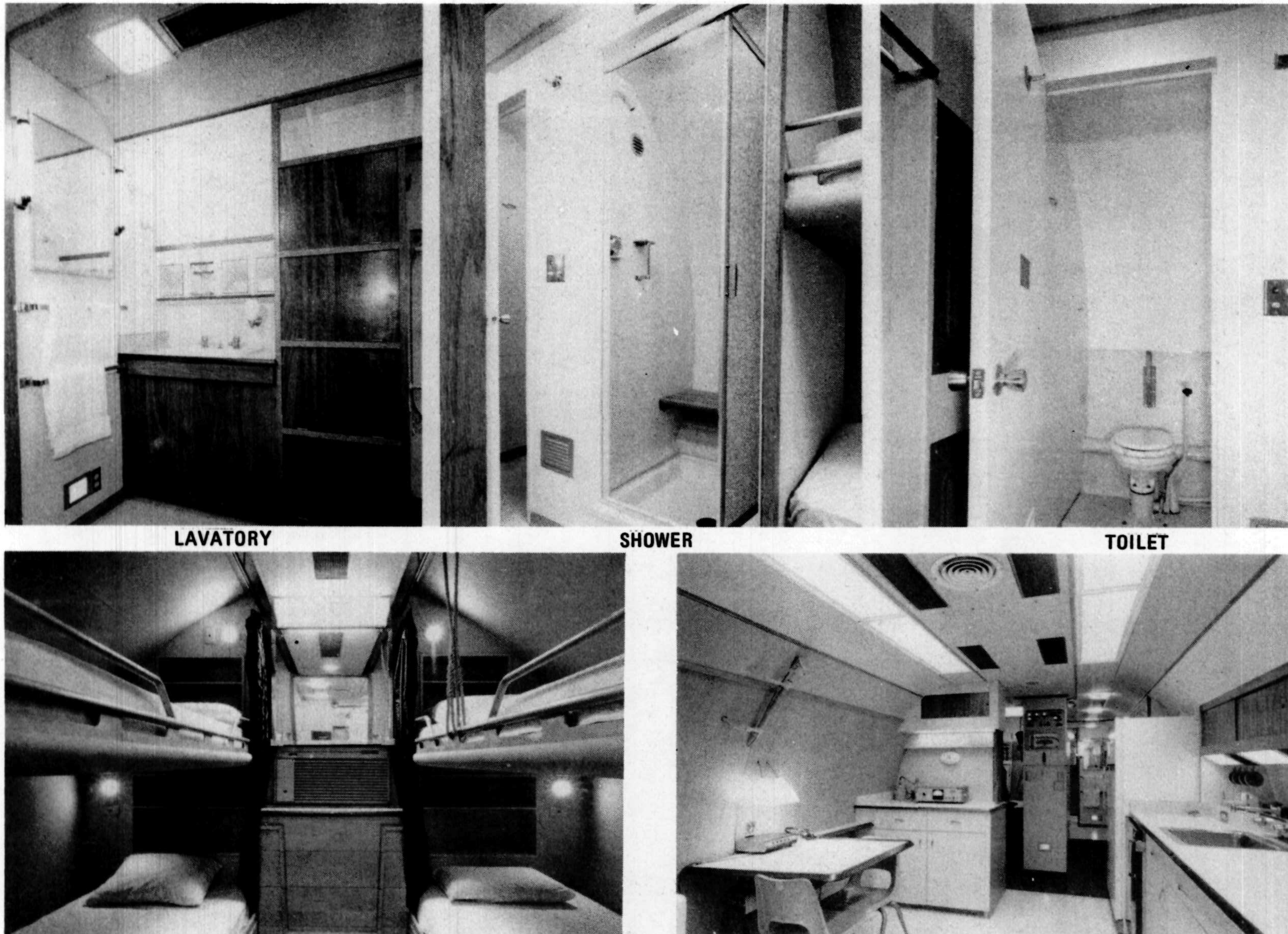

Figure 6. Module Interior

Figure 7. Hub Station

Figure 8. Ladders and Elevator Cart

water reservoir for fine balance. Differences of approximately 200 pounds can be detected, and corrected for, between one end of the beam and the other.

Work stations, located at radii of 30 and 78 feet, house adjustable couches oriented in the horizontal position to align the body of the test subject with the artificial-gravity vector (fig. 9). The lateral orientation of the couches may be adjusted by the test subject from a position facing toward the trailing edge of the beam (anti-spin) in 45-degree increments to a position facing the leading edge of the beam (pro-spin). The position facing up has been designated the axial position. The couch is instrumented so that the position is recorded in the control room. The helmet is held by a head clamp that is instrumented to record rotary head movements between 80 degrees left and 80 degrees right (160 degrees arc). These stations are equipped with modified Langley decision response time devices (DRT)*, which present the test subject with two light displays located approximately 75 degrees to either side of neutral. The lights are sequentially deactivated by four switches located on a pistol grip (fig. 10) in accordance with a code that is presented to the test subject. The following test situations were programmed during the conduct of the present evaluations:

1. Standard (STD) - A code is presented (e.g., 4132) with each number representing the finger that corresponds to a light. The first light is deactivated, the code disappears, and an alternate light is lighted, which, in turn, is deactivated by the appropriate switch until 25 lights have been canceled. The BEGIN SET switch is pushed, the circuit is transferred to the alternate display, with the presentation of a new code, which disappears upon deactivation of the first light. This code may be recalled by closing a circuit during a problem set, if required. Closing the wrong switch during a problem set is recorded as an error.

2. Continuous Run (CR) - The same as No. 1 except that the display is automatically activated without activation of the BEGIN SET switch. Problems continue to be presented until the mode is changed by an exterior operator. Activation of a switch on the control console by an assistant transfers the presentation of lights to the alternate display.

3. Continuous Code Change (CCC) - This mode is similar to STD except a different code is presented with each new light in the series of 25 light-code combinations.

*The DRT was invented and developed by R. M. Chambers, R. E. Kinneman, and J. L. McConnell of NASA-LRC. Patent has been applied for.

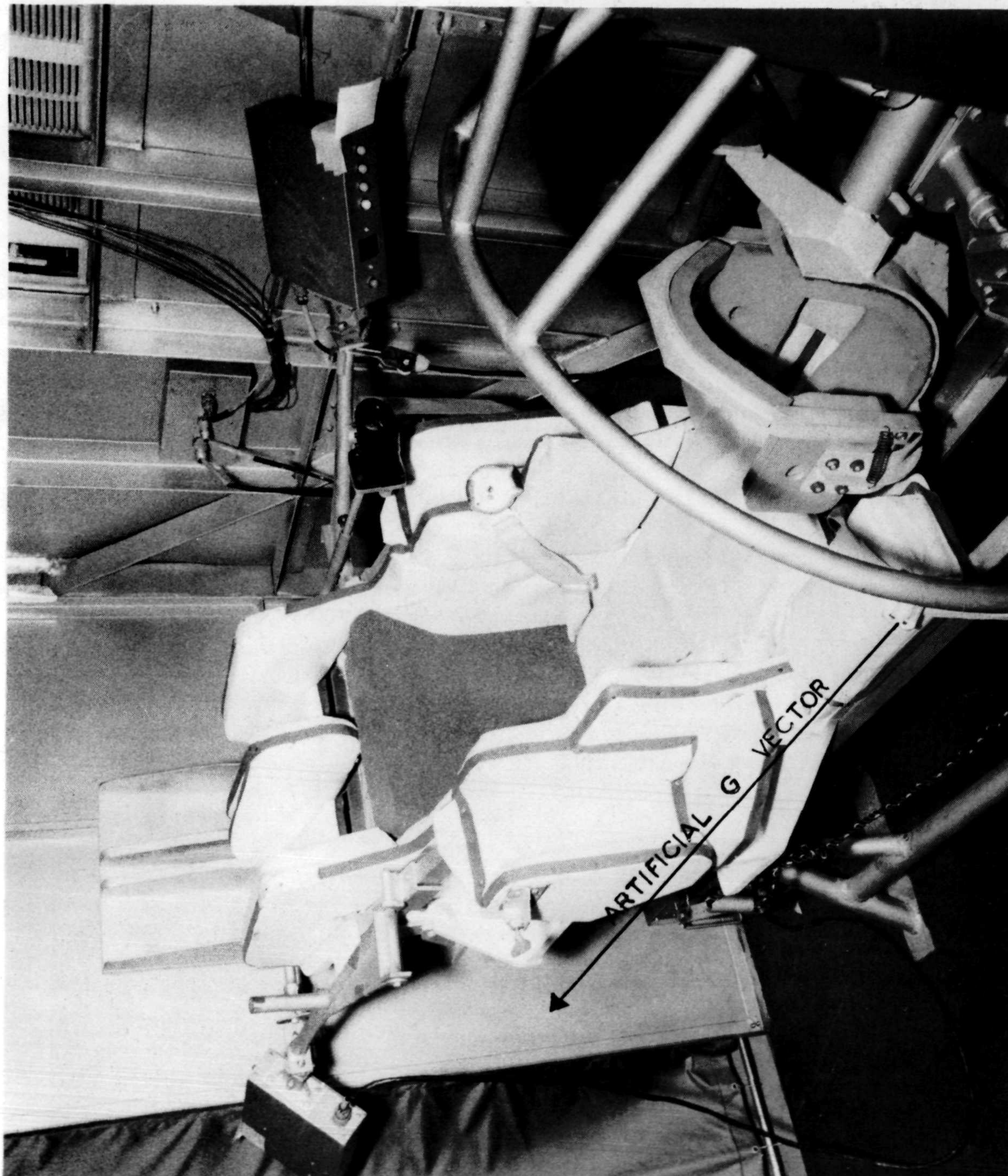

Figure 9. Test Station Couch

Figure 10. Decision Reaction-Time Device

4. Alternate Displays (AD) - This mode is similar to STD except the activated light is automatically switched to the alternate display. Each light is deactivated until 25 light sequences have been completed. This mode requires the test subject to rotate his head approximately 160 degrees between each light.

The chair at the hub station is oriented normal to the earth's gravity. The DRT incorporated into this station has a single display and all modes except AD are available.

A movable enclosure (walking room) is cantilevered from the trailing edge of the beam and may be positioned on the counterbalance end of the beam at radii of 20, 40, 60, or 70 feet. The test subject is supported by a sling system on a trolley located 20 feet above the floor to reduce the effects of the earth's gravity field (fig. 11). The walking surface is 15 feet long, permitting the test subject to walk tangentially in either the pro-spin or anti-spin directions while carrying cargo. When the walking room is located at any given radius, the artificial-gravity vector varies from the end of the room to the center of the beam. The surfaces of the floor and wall are gridded with carpet of 12-inch squares, permitting evaluations of locomotion with respect to body angle, stride length, etc. (fig. 12). A cargo storage cabinet is located at the pro-spin end of the room. Weighted boxes are removed from one bin, rotated, and placed in an alternate cubicle (fig. 13). Time of handling is used to score this activity.

The Langley complex coordinator device (LCC) was used in the crew module only, being oriented with the test subject facing the direction of rotation (pro-spin), opposite the direction of spin (anti-spin) or toward the hub (radial) (fig. 14). The LCC device measures the fine motor control of both hands and both feet by requiring the simultaneous matching of a pre-programmed sequence of four sets of matched lights. The time to perform a series of 50 quadruple matches is used to establish the score. Use of more than a pre-selected time for the matching of one set of four lights results in the recording of a red light (error).

The Stromberg dexterity device is composed of a color-coded board with a series of round blocks that must be moved from a horizontal row into vertical color-coded holes or from a vertical row into horizontal holes (fig. 15). This relatively simple test requires rather extensive arm and head movements. The Stromberg dexterity device was modified to utilize 18 fewer pegs and holes. Further, the pegs were reduced to 3/4 of an inch and equipped with magnets to permit use in an inverted position. The modified version of the test was used at the hub station in an effort to measure the effects of moving from the rotating to the nonrotating environment.

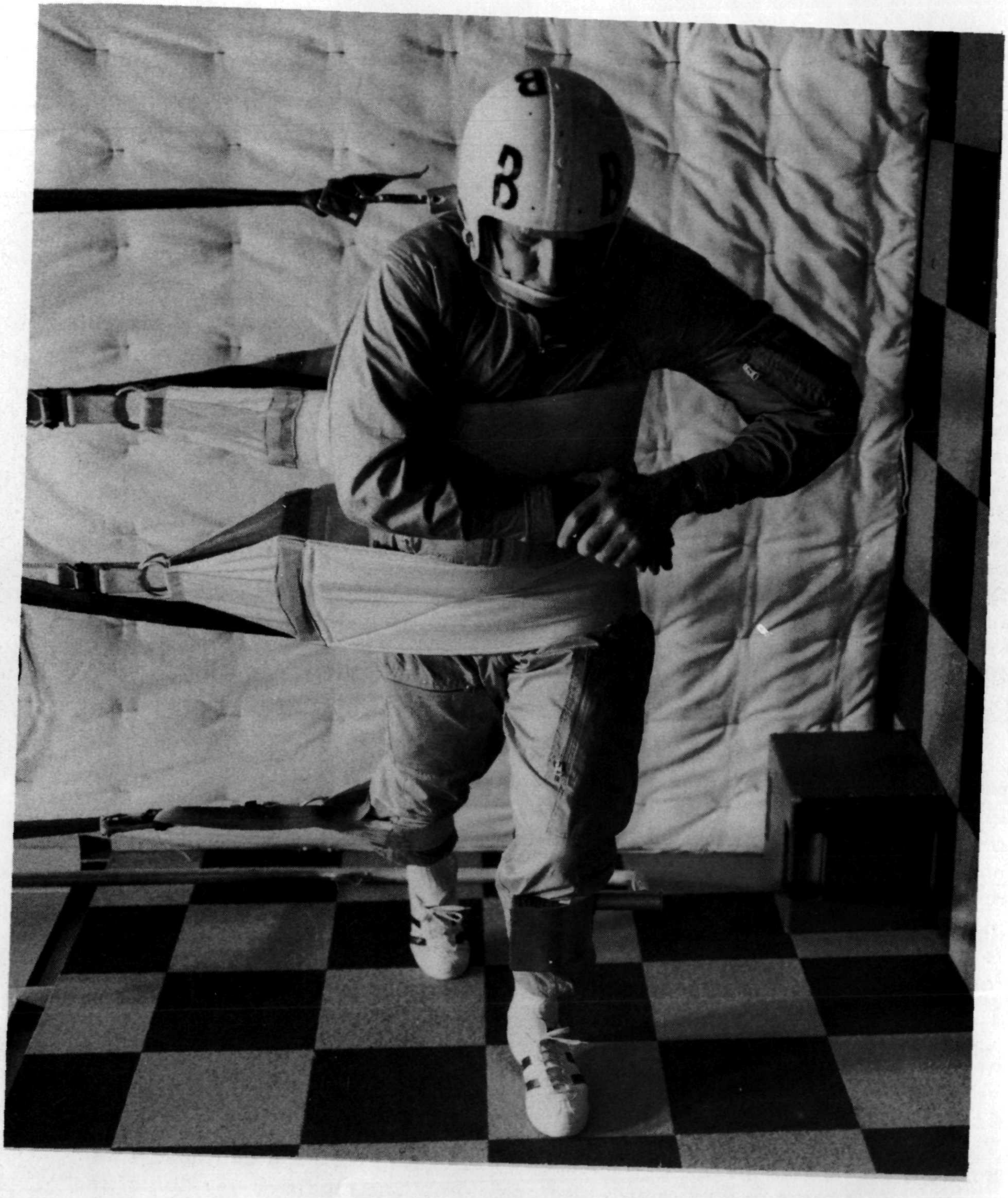

Figure 11. Sling System in Walking Room

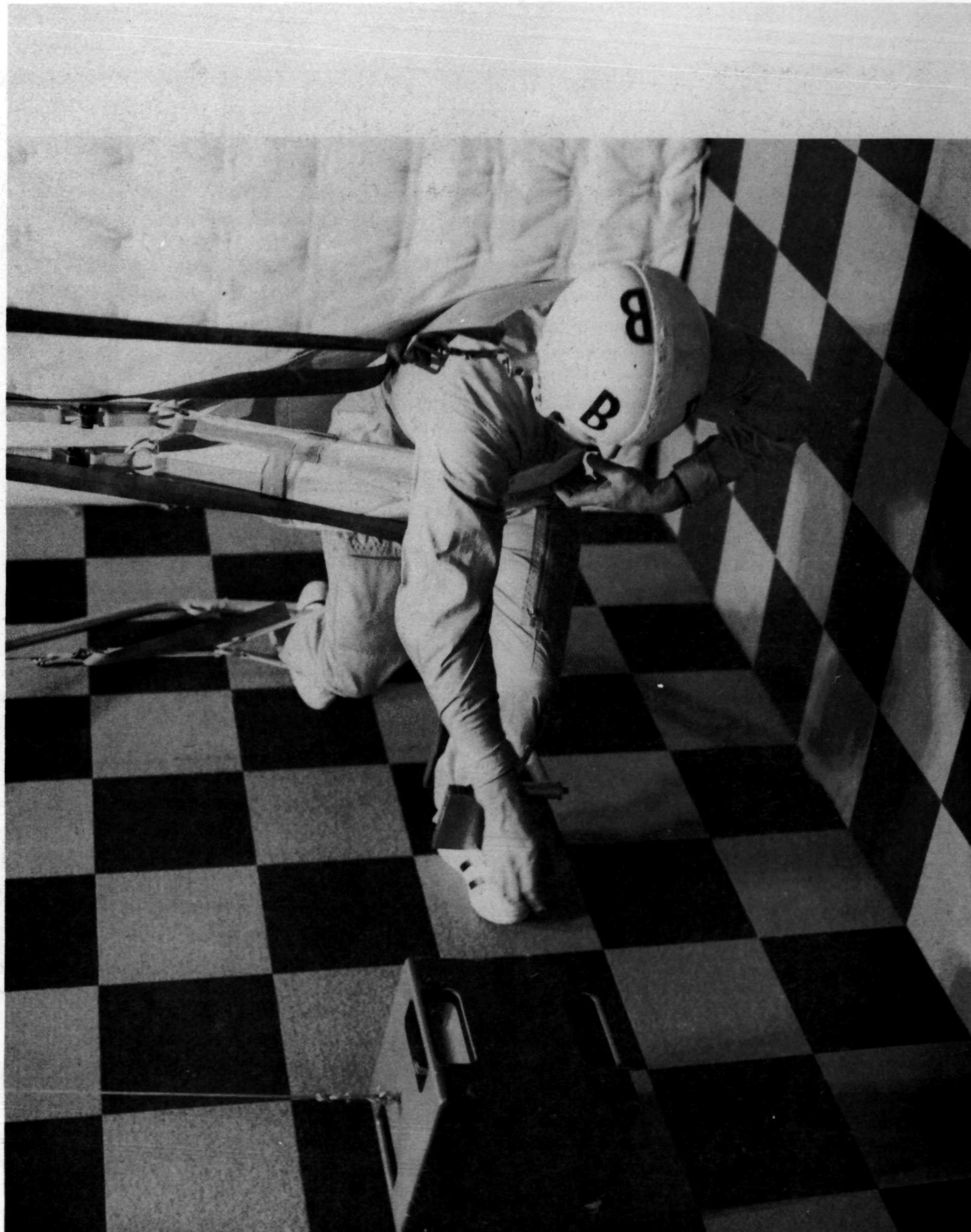

Figure 12. Retrieving Cargo Mass

Figure 13. Cargo Handling

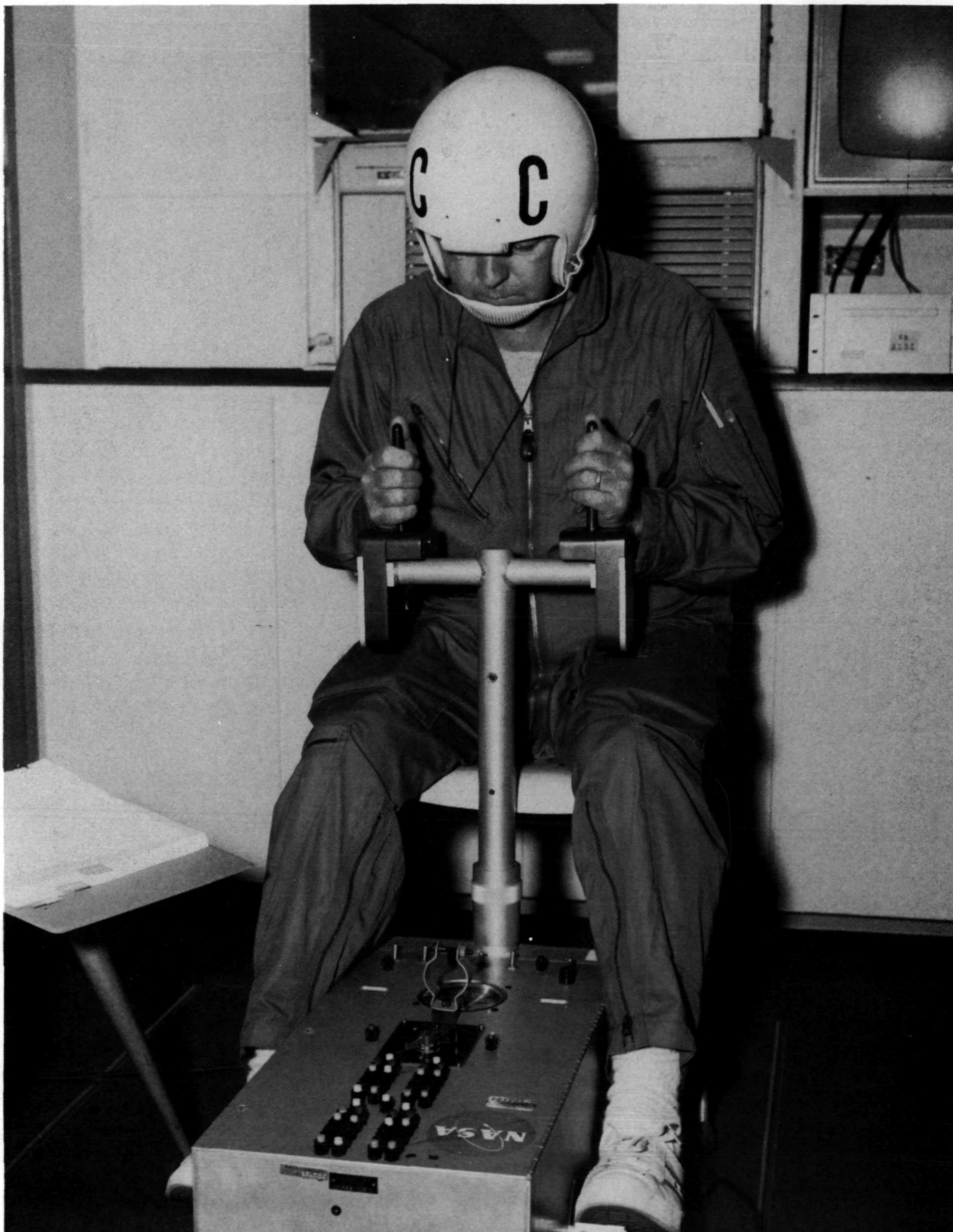

Figure 14. Langley Complex Coordinator Device

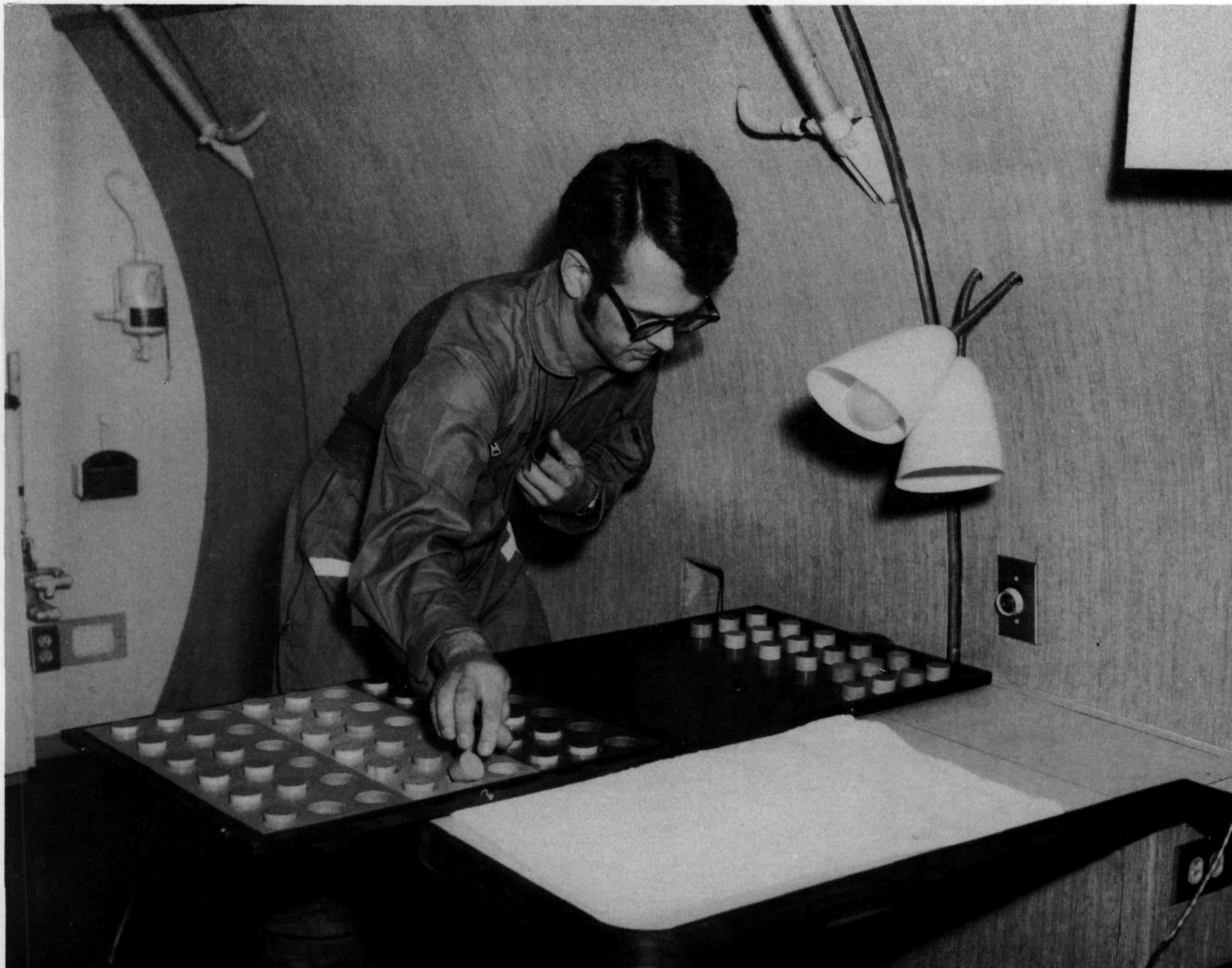

Figure 15. Stromberg Dexterity Device

A single-channel tape recorder is used to present problems during the mental arithmetic tests, as well as to schedule and time head movements used in association with certain of the tests conducted in the crew module (fig. 16). The tape recorders were also used during the daily debriefing sessions conducted by the experiments monitor.

A memory drum apparatus was obtained to evaluate short-term memory and serial verbal learning. The unit consists of a mechanized drum 8 and 1/2 inches wide on which as many as 30 lines of verbal information can be mounted. Various slits are provided to permit the exposure of one to three lines of material at a time. The time of presentation is controllable between one-fourth and ten seconds. A selected group of trigrams (three-letter syllables) is presented to the test subjects for recall.

A pursuit rotor, consisting of timer, an electrical stylus, and a rotating plate with a 1.0-inch electrical contact placed near one edge, was used to test hand-and-eye coordination. This was accomplished by measuring the time the stylus could be held on the electrical contact while the rotary disc turned at a pre-selected rate of 60 rpm. An internal timer provided a 20-second rest between trials.

Vision testing was obtained daily with a Keystone orthorater(R) to evaluate the impact of the rotating environment on near vision and accommodation. A biometrics eye movement monitor was installed to measure the degree of nystagmus induced by the environment.

Telemetric electrocardiographic transmitters were worn by all test subjects during the day. The electrocardiogram (EKG) was displayed on a 14-inch CRT visoscope continuously, and selected tracings were recorded periodically on a Sanborn paper-trace recorder.

An Offner Model T eight-channel dynograph electroencephalographic recorder was used in the crew module to record electroencephalogram (EEG) tracings on the four test subjects on sequential evenings during the seven-day test. An NR-SD-developed head band employing six saline-saturated sponge electrodes and a ground was used in lieu of needles for these studies. One of the bunks was screened to eliminate extraneous radio frequency (RF) electronic signals.

Daily blood pressure measurements were obtained during the rotational periods with a standard sphygmomanometer with aneroid gauge and a Ford-Bowles stethoscope. The blood pressure measurements in the laboratory were obtained with a mercurial baumanometer. The aneroid gauges were calibrated against the mercury manometer to assure accuracy.

Figure 16. Head Movements Scheduled on Tape Recorder

SECTION II
EVALUATION TECHNIQUES

Test Subject Selection and Biomedical Evaluations

Engineering personnel who volunteered to serve as test subjects were initially screened by giving them the equivalent of an FAA class II clinical examination. This examination included clinical fluid chemistries, chest X ray, resting EKG, and audiometry and vision testing. Following the completion of this battery, the individuals were subjected to a treadmill stress test. It required walking three minutes each at 1.7, 3.0, 4.0, and 5.0 miles per hour with the treadmill set at a 10-percent grade. An EKG, blood pressure, pulse rate, and recovery values were obtained to determine physiological fitness. This evaluation was performed by the cardiology department of Memorial Hospital of Long Beach. Those test subjects successfully completing the gross selection criteria enumerated were evaluated psychologically. The Minnesota Multiphasic Personality Inventory (MMPI) and the Gilford-Zimmerman Temperament Survey (GZT) were used.

Additional physiological measurements administered in the Life Sciences laboratories included work capacity tests, pulmonary function evaluations, tilt-table examination of orthostatic tolerance and electroencephalography. The treadmill ergometry was performed at a walking rate of 3.5 miles per hour, with the treadmill inclination increased one percent each minute until the test subject reached a heart rate of 180 beats per minute. Blood pressures, pulse rates, and EKG's were obtained each minute during the test and during three minutes of recovery. Pulmonary function was evaluated with a Cambridge Pulmonary Function Tester, with functional residual volume determined by the closed-circuit helium technique. Calculated values included residual volume, one- and three-second forced vital capacity, and the residual volume/total lung capacity (RV/TLC) ratio.

A resting EEG was obtained on each test subject. An Offner Model T Dynograph Recorder, with modified lead configurations of eight channels, was used. These tracings were evaluated by the Division Medical Office with the assistance of consultant personnel.

A major contribution to the selection criteria was the vestibular calibration tests. Volunteers who successfully completed the tests enumerated were sent to the Naval Aerospace Medical Research Laboratories in Pensacola, Florida, for evaluation of the auditory, visual, proprioceptor, and vestibular systems. Caloric thresholds were determined by the technique of McLeod and

Meek (ref. 13) utilizing caloric stimulation coupled with electronystagmography. Labyrinthine direction and preponderance was determined by a modified Hallpike technique (ref. 14) in the dark with the subjects' eyes open. Sensitivity of the horizontal semicircular canals to angular acceleration was determined by the perception of oculogyral illusions (OGI). The OGI was elicited with the subject seated in a chair producing very small magnitude accelerations while he observed a fluorescent line in a goggle device (ref. 15 and 16). Otolith function was measured by the technique of ocular counterrolling, recorded while the body was tilted 90 degrees right and 90 degrees left from the upright (ref. 17). Postural equilibrium (ataxia) was measured by the techniques of Fregly and Graybiel (ref. 18 and 19). The Dial Test developed by Kennedy and Graybiel (ref. 20) was administered in the Slow Rotation Room (SRR) to measure susceptibility to motion sickness. This was also evaluated in a chair device, and the technique of Miller and Graybiel (ref. 21) was used. This work was done by Dr. Graybiel and his staff and required two days per test subject.

One-day tests. - Body weight, blood pressure, and pulse rate were obtained by biomedical monitoring personnel before and after each day's testing. Nude body weight was measured by a clinical beam balance to plus or minus 0.25 pounds. Blood and urine samples were collected during the first 6 one-day tests. The urine samples collected during the pre- and the post-test periods were analyzed for specific gravity and pH. The blood hematocrits were determined from fingertip blood with heparinized capillary tubes.

Heart rate was monitored continuously during the rotational test periods by a Signatron EKG telemetry system. The EKG signals from each subject were continuously displayed and periodically recorded.

Three and seven-day tests. - Body weight, blood pressure, and pulse rate were recorded as described. Pulmonary function and tilt-table examinations also followed previous protocol. Work capacity was determined before and after each of the two tests, with a Godart Bicycle Ergometer, during two 5-minute segments. The resistance was set at 75 and 150 watts, respectively. Blood pressure and pulse rate were obtained during each minute of work and for a three-minute recovery period. In addition, respiration rates were recorded at one-minute intervals. One-minute respiratory volume, oxygen consumption, and carbon dioxide production were determined at minutes 5 and 10, and the respiratory quotient was calculated. Respiratory gas was collected, using a No. 4 Foregger anesthesia mask with a Hans Rudolph high-velocity breathing valve connected to a 120-liter neoprene-latex meteorological balloon. The gas was withdrawn from the collection bag through a precision wet-test-type gas meter and analyzed for oxygen and carbon dioxide content.

Blood pressures and pulse rates of the test subjects were measured during the rotational test periods upon arising, at noon, and in the evening.

Vision testing was conducted each evening with a Keystone orthorater and test cards. The EKG's were recorded at random intervals during the day for heart rate determinations. Electrodes were removed during the night to reduce skin irritation. Test subject activities were monitored continuously by closed-circuit television and audio systems. Pre- and post-rotation blood samples were collected, and complete blood chemistry analyses were accomplished by a local clinical laboratory.

EEG tracings were obtained on all test subjects during the rotation, with a different individual being instrumented each night. The Offner Model T eight-channel dynograph was used in conjunction with a soft-electrode system developed at NR-SD for use in test situations. The recordings were obtained for approximately two hours each evening, after the individual had retired. The EEG head band was fitted and tested, and the test subject was permitted to retire in the specially screened bunk. Monopolar tracings were obtained with the six electrode placement as follows:

1-3 Left frontal to left parietal
3-5 Left parietal to right frontal
2-5 Right frontal to left occipital
1-5 Left frontal to left occipital
2-4 Right frontal to right parietal
4-6 Right parietal to right occipital
2-6 Right frontal to right occipital
1-6 Left frontal to right occipital

The tracings obtained in this study were transmitted to the NASA-LaRC technical representative for reading and evaluation by a NASA consultant.

Test Subject Training

A regular program of training was employed to raise the performance of the test subjects before formal testing, to familiarize the subjects with experiment tasks and the proper method of performance, and to instruct the subjects relative to the overall objectives of the test program. The first objective was satisfied by formal training on the actual test devices, initially in a laboratory environment, and finally, wherein possible; on the RTF. For tasks in which complete simulation was not possible, part-task training was employed. For the remaining two training objectives, briefings, instructions, and dry runs were used to prepare and instruct the test subjects. In addition, familiarization runs in the rotating environment on the RTF were provided to acquaint the test subjects with the various forces. All training was conducted during normal work hours in a normal work week. Formal training before each of the three test series (one-day, three-day, and seven-day) varied as to the specific protocol for each device and the test subjects who were in training. These are discussed here.

One-day-test-series training. - Four test subjects, designated A, B, C, and D, were prepared for this series. Although more than four subjects received some training before final selection, only the four final test subjects will be discussed in detail. All the test subjects were naive regarding the test devices when formal training began, approximately six weeks before the eight-hour-test series in the laboratory area. Approximately two weeks before the eight-hour-test series, training was initiated on the RTF. For each experiment task, specific training procedures were used before the one-day-test series.

Langley complex coordinator (LCC) device: The subjects performed 20 cycles (1000 problems) each day, ten cycles in the morning and ten cycles in the afternoon. Each subject recorded his own score. The subject was instructed to concentrate on decreasing his time score and to use the interval timer (IT) aspect of the LCC as a measure of errors. As the subject's performance increased, he lowered the IT to maintain >25 errors. This acted as a training aid to increase performance. Baseline performance for the LCC was recorded on the day before initiation of the rotational tests and during the week after completion of the 12 runs of the one-day-test series.

Decision response time (DRT) device: The test subjects performed 12 cycles (300 problems) on the DRT each day during the training period. All training was conducted in the standard mode (one code provided for each 25 problem cycle). Test subjects were instructed to strive to obtain the lowest possible performance time with minimum errors. The subjects recorded their own scores. Baseline performance values for the DRT were recorded the day before initiation of the test and during the week after completion of the 12 one-day tests.

Standard Stromberg (STROM): The test subjects performed six trials each day, working in pairs, with one subject performing the task, while the other timed the task and recorded the scores. Test subjects were instructed to strive for the lowest possible performance time. If errors in placement of the pegs were made, or pegs were dropped, the subjects corrected the problem and continued. These errors were noted in the score forms. Baseline performance scores for the STROM were recorded one day before initiation of the test and during the week after completion of the 12 one-day tests.

Modified Stromberg (MOD. STROM): The test subjects performed three trials per day during the training period, with each subject recording his own scores since this was the procedure to be used during the actual test series.

The test subjects were instructed to strive for the lowest possible performance time. If errors in placement of the pegs were made, or pegs were dropped, the subjects corrected the problem and continued. These errors were noted in the score forms. Baseline performance values for the MOD. STROM were recorded one day before initiation of the test and during the week after completion of the 12 one-day tests.

Postural equilibrium (ataxia): Each test subject performed the Graybiel-Fregly ataxia battery (ref. 18) daily during the training period. Test monitoring personnel timed and recorded the scores. Baseline performance scores were recorded the day before initiation of the one-day-test series and during the week after completion of the 12 one-day tests.

Ladder, elevator, and walking-room tasks: Simulation of these tasks was not possible without rotation. Therefore, only part-task training was provided. Sling and sub-gravity familiarization was provided through a sling system suspended above a treadmill that had been positioned on one side to allow the test subjects to walk with his body horizontal with respect to the earth. In addition, briefings, dry runs (walking on the RTF) and performance trials of each task were conducted to insure familiarity with task procedures and overall objectives.

Three-day and seven-day test training. - In addition to three test subjects (A, B, and D) previously used in the one-day tests, two additional test subjects (F and G) were qualified and trained for the long-duration tests. For the experienced test subjects, training was reinitiated approximately two weeks before the rotational test. For the new individuals, it was begun approximately four weeks before rotation. All training was performed in the laboratory area, except for the last two days, which was performed on the RTF. Task briefings and familiarizations were given to all test subjects relative to the new tasks, and the new test subjects were familiarized with all tasks as outlined in the paragraphs that follow.

LCC: The experienced test subjects performed 10 cycles (500 problems), and the new test subjects performed 20 cycles (1000 problems) daily. Subjects were instructed as before in the operation and objectives of the LCC task. Pre- and post-rotation baselines were recorded during the weeks before and after the rotational test periods.

DRT: During the first two weeks of training for the new test subjects, 12 cycles per day were performed. During the last two weeks of training, all subjects performed 10 cycles of standard mode (STD), 10 cycles of continuous code change mode (CCC), 2 two-minute runs of the continuous run mode (CR), and during the last two days of training on the RTF, 4 cycles of the alternating displays mode (AD). Subjects were instructed in proper equipment operation and the accurate recording of data, as described. Pre-test baselines were recorded on the RTF during the week before the rotational test.

STROM: All test subjects performed six trials each day. They were instructed in procedures, and scores were recorded as described for the one-day tests. Pre- and post-test baseline performance scores were recorded the week before and the week after the rotational test exposure.

Postural equilibrium (ataxia): Each subject performed the Graybiel-Fregly ataxia battery each day, during rotation. Performance was timed and recorded by test monitoring personnel. Pre- and post-test baselines were recorded during the week before and after the rotational test.

Ladder, elevator, and walking-room tasks: The new subjects were familiarized with these tasks, as described, before the one-day tests. Since there were no changes to the protocol from the one-day tests, no additional training was required for the experienced test subjects.

Pursuit rotor (PR): All test subjects performed three groups of three (or nine) 20-second trials each day during the week before the rotational test. Initially, the PR rotational rate was set to 45 rpm, while training on the final day and during rotation was done at 60 rpm. The test subjects recorded their own scores for each group of 20-second trials. Pre- and post-test baselines were recorded during the week before and after the test.

Memory drum (MD): Each subject performed one trial a day during the week before the rotational test. A trial consisted of viewing and recalling ten trigrams. Correct answers and performance times were recorded by the test subjects in the same manner as on the RTF. Test personnel monitored the subject's performance to insure understanding and compliance with established test procedures. All test subjects received the same list of trigrams on the same day, with lists being changed each day. Pre- and post-test baselines were recorded during the week before and after the rotational test period.

Mental arithmetic (MA): All test subjects performed one trial set of ten arithmetic problems per day during the week before the test. Each test subject used a different one of the six training tapes each day until all tapes were used. He performed the task as it was to be performed during the rotational test, including the recording of his answers. Pre- and post-test baseline performance was recorded during the week before and after the rotational test.

Formal test procedures and protocol. - Each test subject employed in the test series was exposed to all of the experimental conditions for each of the performance tests evaluated. This procedure was designed to reduce or eliminate individual differences as a source of error in the data. Because of the large number of experimental conditions and performance measures obtained, it was necessary to group the experiments so that different experiments were being performed either simultaneously or concurrently, with different performance measures scheduled sequentially at the various test stations of the facility. This complexity in scheduling, as well as other constraints, does result in some minor compromise in statistical balancing procedures. Thus the experimental design for a number of the test procedures cannot be regarded as ideal with regard to counterbalancing sequences (ref. 22). However, validity of the test results should not be seriously affected by this complexity. The test subjects were arbitrarily assigned the identifying letter symbols of A, B, C, D, E, F, and G, which were applied to the helmets to facilitate test subject identification during TV monitoring and motion picture documentation. Log books of subjective comments, debriefings, and other commentary were recorded for subsequent evaluation.

Test protocol.

One-day tests: The 12 one-day tests were performed at the rate of two test days per week, with alternate days used for data reduction, facility modification, and maintenance. The tests to be performed by the four test subjects were grouped into five major test periods for each of the 12 days of testing. The first period of each day was allocated for facility preparation, test subject evaluation (medical), and the collection of baseline performance data on the LCC device before facility spin-up to the scheduled rotation rate. The three remaining test periods were the LCC/DRT, STROM/ladder, and elevator/cargo/walking evaluations.

Test periods were counterbalanced for statistical interrelationships and were performed in the rotating mode. This counterbalancing resulted in four major test event sequences, each occurring once for each of the three rotation rates. The final period of each test day was allocated to performance of the ataxia test battery immediately after cessation of facility rotation. A typical test schedule is presented in table 1.

Three- and seven-day tests: The principal objectives of the three- and seven-day tests were (1) to evaluate the impact of artificial-gravity simulation on test crew performance, (2) to evaluate the time-sequence and impact of adaptation on performance, (3) to compare the effects on personnel with extensive familiarity with the rotational environment (obtained during the one-day series) with individuals whose experience in the rotational test program was limited to calibration and indoctrination exposure. The gross experimental conditions were basically the same in these longer tests as described for the one-day tests. The rotational rate was a constant 4 rpm, and the walking room was placed at 40 feet. This was done so that the performance

TABLE 1. - TYPICAL TEST SCHEDULE

Time Allocated	Event
7:45 - 8:00	LCC Baseline Testing (Pre-rotation)
8:10 - 8:15	Spin-Up
8:15 - 10:55	Primary Psychomotor Tests
10:55 - 11:40	Rest and Lunch Break
11:40 - 2:00	Wall Walking & Cargo Handling Ladder Climbing
2:00 - 2:10	Rest Break
2:10 - 2:50	Stromberg Dexterity Test Elevator
2:50 - 2:55	Spin-Down
2:55 - 3:25	Ataxia Test Battery (Post-rotation)

on a flat floor at a similar radius as would apply to the Skylab configuration could be evaluated. A typical time line is presented in table 2.

Gross performance test procedures.

Tangential locomotion: These tests were performed while the test subjects were suspended in a horizontal orientation by means of a sling system. The sling aligned the individual longitudinally with the radial vector. This system, which reduces the effect of the normal 1-g earth vector, was designed to provide minimum drag resistance while the test subjects walked tangentially

TABLE 2. - TYPICAL TIME LINE FOR THREE- AND SEVEN-DAY TESTS

0600	-	Reveille
0600	-	Blood pressure (20 min.)
0620	-	Personal hygiene, housekeeping, food preparation and breakfast (1 hr. 40 min.)
0800	-	Briefing and instrumentation (30 min.)
0830	-	Work Period (3 hrs.)
0830	-	Elevation/Stromberg Series (1 hr.)
0930	-	Psychomotor Test Series 2 (2 hrs.)
1130	-	Blood pressure (20 min.)
1150	-	Lunch and free time (2 hrs.)
1350	-	Work Period (3 hrs. 30 min.)
1350	-	Locomotion Series (1 hr. 30 min.)
1520	-	Psychomotor Test Series 1 (2 hrs.)
1720	-	Ataxia (20 min.)
1740	-	Debriefing and remove instrumentation (30 min.)
1810	-	Orthorater Team #1 (20 min.)
1810	-	Dinner preparations - Team #2 and eating
2000	-	Blood pressure (20 min.)
2010	-	Orthorater Team #2 (20 min.)
2200	-	Subject 2 (EEG) Preparation (10 min.)
2210	-	Subject 2 (EEG) (6 hrs.)

on a vertical floor (wall). The tests were accomplished by two-man teams, with each test subject assisting the alternate into and out of the sling system, activating the movie camera, and recording time of performance. The test subjects performed ten traversals of the vertically oriented walking surface per session, i.e., five in the pro-spin and five in the anti-spin direction. The test subject was required to back up or be assisted back to the starting position each time between traversals. The tests were performed at rotational rates of 3, 4, and 5 rpm, with the movable enclosure located at 20, 40, 60, or 70 feet from the axis of rotation on different days of the one-day test program. The floor was located at 40 feet, and the RTF turned at 4 rpm during the three- and seven-day evaluations. The test was self-paced, and the measure of performance was time required for each traversal, and, more important, the subjective comments. Motion pictures were obtained for selected traversals during each day.

Tangential cargo transport: This test was performed in conjunction with, and under the same conditions as described for, the tangential locomotion tests. The cargo packages were represented by one-foot cubes each weighing 32 pounds. They were suspended by a separate sling system to reduce the effects of the normal gravity vector. The test subject carried the package during two traversals of the walking surface, facing both the pro-spin and anti-spin directions. He also evaluated the effect of setting down and picking up the package and continuing the walk.

Cargo handling: This test was performed under the same experimental conditions as described for tangential locomotion and tangential cargo transport except that it was accomplished in the pro-spin direction and in one end of the walking room only. The test procedure consisted in the removal of four one-foot cubes (about five pounds), representing cargo packages, from receptacles in an eight-chambered cabinet, rotation of the cubes about two axes, and reinsertion of the cubes into the receptacle at a higher or lower level. This task was repeated four times in each direction, raising the cubes or returning them to their original locations at the lower level. The test was self-paced, and the measure of performance was time required for total task accomplishment. Subjective responses were also reported and/or recorded.

Radial locomotion (ladder climbing): The test subjects were suspended in the horizontal position by means of a sling system similar to that used in the tangential locomotion test, with the longitudinal axis of the body aligned with the radial vector. Each test subject was assisted into and out of the sling by the alternate member of the two-man team. The test subject alternately ascended and descended either of two radially oriented ladders, facing alternately in the pro-spin and the anti-spin directions. Two ascent-descent cycles were performed in each of the two orientations. The test was repeated four times for each of the three rotation rates during the one-day test series. The tests were self-paced, and the measure of performance was time required for each traversal. Motion pictures were obtained for selected ascent-descent cycles in each orientation. During the seven-day test, a rope was stretched between the ladders and evaluated for potential use in the radial ascent-descent mode. The test subject, suspended in the sling system, moved hand over hand along the rope facing alternately pro- and anti-spin directions. Subjective comments were recorded.

Passive radial transfer (elevator): The test subjects passively rode in a powered cart mounted on a radially oriented rail system between the two ladders. The test subjects were aligned with the radial vector and exposed to two ascent-descent cycles each while facing the pro-spin, the anti-spin, and axial (facing upward) directions while traveling at linear rates of 2, 4, or 6 feet per second during exposure to each of the three rotation rates. No performance measurements, other than subjective comments, were available for this test. However, a limited correlation of heart rate rotational rate, linear rate, and body position during the passive transfer was attempted. On the basis of data obtained during the one-day tests, this evaluation was eliminated during the three- and seven-day tests to permit the incorporation of additional psychomotor tests as discussed in the paragraphs that follow.

Psychomotor test procedures.

Head movements: Standardized head movements were incorporated into the test protocol during the three- and seven-day tests. The affected experiments included LCC, Standard Stromberg, pursuit rotor, memory drum, and mental arithmetic. The equipment used was a tape recorder equipped with earphones, a footage counter, and controls. Special tapes were prepared which provided time, number, and sequence of head movements. An example of the instructions on the tapes is presented in table 3. A set of head movements was repeated either five or ten times according to the experimental design schedule. The instructions for head movements used in conjunction with the Mental Arithmetic were were included in those specific tapes. Prior to the conduct of an experimental task, the test subject would select the proper head movement tape, providing instructions for either five or ten sets of head movements, and prepare the tape recorder. At the point in the experimental task where the head movements were scheduled the subject would seat himself on a chair, activate the tape recorder and follow the recorded instructions. The head movements were done so that the head was placed 90 degrees to the rest or center position at each command. After the required head movements were completed, the tape recorder was deactivated, and the experimental task was then completed.

TABLE 3. - TYPICAL HEAD MOVEMENT INSTRUCTIONS

Time in Seconds	Instructions
00	"This is head movement tape No. -----"
15	"Ready for head movements"
25	"Right"
27	"Center"
30	"Left"
32	"Center"
35	"Forward"
37	"Center"
40	"Back"
42	"Center"
44	"Rest"
50	"Right
	Etc.

Langley complex coordinator device (LCC): The LCC was used to evaluate complex psychomotor activity in the rotational environment that required hand, foot, and eye coordination similar to piloting skills. These evaluations were performed during the three rotational rates and the test subject was orientated in the pro-spin, anti-spin, and axial configurations with respect to the axis of rotation. The LCC was used in the crew module at a radius of approximately

75 feet. Since the floor of the crew module automatically orients normal to the resultant g vector, the test subjects were able to sit normally in a chair while performing. The LCC task consists of a trial of 50 problems, each problem requiring the alignment of four manually controlled lights with four randomly programmed lights. The alignment is accomplished by the simultaneous manipulation of two hand controllers and two foot pedals, one for each set of lights. The objective of the task was the simultaneous alignment of the four sets of lights in the minimum time. Two criteria of performance are available: total trial time (to one hundredth of a second) and the number of times the interval time (IT) between problems is exceeded. The IT is a pre-selected value that by operational definition should be exceeded no more than 25 times per trial. This value for IT was determined during training. The experimental task consisted of performance by each subject of two warmup trials followed by two baseline trials each day before rotation. While the pre-rotation baseline is being established, subject order and orientation were not considered. During rotation each subject performed eight trials. The subject initially positioned himself and the LCC in the first of the three task orientations facing pro-spin, anti-spin, and radially. At this first orientation he performed two warmup trials and then two experimental trials. After this he proceeded to the two remaining orientations, where he performed two trials at each orientation. The test subject recorded in a log book name, date, time, IT selection, total time per trial, and number of IT lights obtained. The warmup, baseline, and orientation were provided to the subject at the station. During the three- and seven-day tests, the experiment included zero, five, or ten head movements and 90-degree body changes forward, backward, and laterally on a randomized schedule.

Decision response time device (DRT): The DRT was used to evaluate psychomotor performance on a task requiring interpretation of coded instructions before selection of a correct response. Test subject performance on the DRT was measured on the hub station and at the 30-foot and 78-foot stations in the STD mode during the one-day tests. At the 30- and 78-foot stations 100 problems (4 cycles) in the standard mode were completed at each of three orientations, i.e., facing axial, pro-spin, 45-degree pro-spin, and anti-spin, and 45-degree anti-spin each test day. At the hub station, the test subjects completed 100 problems (four cycles) each test day.

The DRT test devices were modified for use in the three- and seven-day test programs. These modifications permitted the scheduling of the STD mode, continuous code change (CCC), continuous running (CR), and alternating displays (AD). The DRT at the hub station was similarly modified, except for the AD mode, since only one display was used at that site.

The DRT standard mode task in the long-duration tests was identical to the one-day tests, except that only two cycles were performed at each orientation, at the 30- and 78-foot stations, while 20 cycles were performed at the hub. These changes were basically made to balance the work load at each station and provide a better basis for interstation performance comparisons. The CCC and AD modes were scheduled for two cycles at each orientation, as in the STD mode, while the CR mode was set for two minutes at one couch orientation. Measures of performance were time for completion of each cycle and total response errors. Baseline data were obtained at the end of the training period and after the final test periods.

Modified Stromberg dexterity test device (MOD. STROM): The modified Stromberg device was designed for use at the hub station. The device was to measure hand-and-eye coordination involving both gross and relatively precise object positioning, after the transition from the rotating to the non-rotating environment. This test was performed during the one-day tests only. The test consisted of removing cylindrical pegs from holes on the left side of a test board and replacing them in holes on the right side in a prescribed sequence with respect to orientation and color coding. Each test subject timed himself on three consecutive trials and recorded errors and the dropped pegs. Data were analyzed with respect to rotational rate, time of day, and replications.

Standard Stromberg dexterity test device (STROM): The Stromberg dexterity test device provided a measure of manipulative ability. It had been found, in earlier tests, to be sensitive to the rotating environment. The experimental task consisted of picking up wooden discs and placing them in holes in either of two prescribed sequences. The criterion of performance was time. Each subject performed two trials at each of three orientations. These trials were timed by stop watch and recorded in a score book by a partner subject. Errors in positioning the discs and dropped discs were also recorded. The test protocol used during the three-day and seven-day tests was the same as for the one-day tests except for addition of scheduled head movements. The task consisted of two baseline trials, followed by either five or ten sets of head movements and four experimental trials. The task was performed at one orientation, varied by test subject and days during the long-duration tests.

Mental arithmetic (MA): The mental arithmetic equipment consisted of a tape recorder with earphone attachments and tapes of arithmetic problems. The tape recorder was equipped with a footage counter to allow the subject to locate specific series of problems, forward and backward, stop and play, and volume controls. Problem tapes were prepared for both static training and rotational testing. A mental arithmetic trial consisted of a combination of ten arithmetic operations with the typical arrangement of four additions, three subtractions, two multiplications, and one division. All trials began with an assumption of zero, never exceeded a value of 100 nor went below zero. All divisions resulted in whole numbers. The numbers used in the trials were chosen from a table of random numbers, and the trial used these numbers and the aforementioned rules. For the rotational experiment, 12 trials were used with five or ten sets of head movements required between trials 6 and 7. This permitted evaluation of performance before and after the head movements. The tapes were recorded to include the trials, the head movements, and the necessary instructions to commence, record, and end the set. Ten seconds were allowed for preliminary introduction of the set of trials; five seconds were allowed between each arithmetic operations; and, finally, 30 seconds were allowed for recording of the answer. A typical problem is presented in table 4.

TABLE 4. - TYPICAL MENTAL ARITHMETIC PROBLEM

Time in Seconds	Instructions
00	"This is mental arithmetic tape No. -----"
10	"Ready for trial No. 1"
20	"Add four"
25	"Add eight"
30	"Subtract one"
35	"Add three
40	"Divide by seven"
45	"Add one"
50	"Multiply by four"
55	"Subtract seven"
60	"Add three"
65	"Multiply by four"
70	"Record your answer and comments"
100	"Ready for trial No. 2"
	Etc.

This test was intended to evaluate cognitive and short-termed memory functions as affected by the rotational environment and head movements. The task required the mental solution of six arithmetic problems for a baseline score, followed by either five or ten sets of head movements, and then six experimental problems. All task problems and head movement instructions were tape-recorded. The test subject was required to write his answer and comments in a special score book. The orientation for the task was facing radially toward the hub and was performed in the kitchen area of the crew module. Instructions for the mental arithmetic test were located at the work station and included subject order and the mental arithmetic problem tape for each test subject.

Pursuit rotor: The pursuit rotor was an experimental task added for the three-day and seven-day tests. This task was designed to investigate tracking behavior involving eye-and-hand coordination. The tasks were performed to evaluate any performance changes in response to the rotational environment and the effects of head movements. The pursuit rotor task was performed in the crew module. It required that the subject maintain contact (track) for 20 seconds with a spring-loaded stylus on a metal disc located on a turntable revolving at 60 rpm. This 20-second trial was followed by a 20-second rest. Three replications of this constituted a set. The total on-target time accumulated on a 1/100-second timer constituted the score for that set. The first set was performed as a warmup. The next three sets constituted the baseline performance. After this, the required head movements were performed, followed by three experimental sets.

Memory drum (MD): The memory drum, added to the three-day and seven-day test protocols, was designed to evaluate subject performance in serial verbal learning and short-term memory in the rotating environment. The task required the subject to attempt to memorize ten trigrams (three-letter syllables) that were successively presented to him in sequence through the aperture of the memory drum at two-second intervals. After viewing the entire sequence, the subject closed the aperture and wrote down in sequence all of the trigrams he could recall. He then covered up his written response and repeated the viewing of the sequence on the memory drum until he felt he had them all correct. He would then run a check on his responses by viewing the sequence with his answers uncovered, recording right and wrong responses. If the responses were all correct he stopped. If he had errors he repeated the sequence. During the viewing of the trigrams on the memory drum, the subject was instructed to sound them aloud. He also timed, with a stop watch, the entire task. Prior to beginning the memory drum task, the test subject performed either zero, five, or ten sets of head movements as scheduled for that station. Each run through the sequence was counted as a trial. This task was performed with the test subjects facing radially only. The initial sequence was placed into the memory drum by the test conductor. Then after a test subject completed his sequence, he changed the sequences for the next individual.

The trigrams were composed of initial and final consonants, with a middle vowel. These trigrams were developed by random selection of vowels and consonants. After a large set was developed, all of them meaningful words, trigrams that sounded like words, abbreviations, or other easily memorized trigrams were removed. From the remaining large collection of trigrams, random lists of ten trigrams were compiled for use with the memory drum. During the training, all subjects used the same list of trigrams each day. However, during the tests on the RTF, each subject had a different list each time he performed the task. This was done to cancel hearing effects and to balance any differences between list difficulty. Two sets of criteria were used for analysis: the number of correct trigrams, both in spelling and order during the first four trials, and the number of trials in which all were correct.

Postural equilibrium (ataxia): The ataxia test battery (short version) developed by Graybiel and Fregly at the U.S. Naval Aerospace Medical Institute (ref. 18) was used to evaluate the degree of adaptation to the rotating environment. The battery was administered each day after cessation of rotation. After the RTF had ceased rotation, the test subjects left the cabin and proceeded to the hub area, where sufficient area existed for administration of the test. Each subject was cautioned to minimize head movements while transferring to the test area and while awaiting his turn to perform the test. Each subject was required to perform four tests, which were timed and scored by the experiments monitor.

Walking on floor, eyes closed (WOFEC): The test subject would perform three trials of heel-to-toe walking on the floor, with eyes closed and arms folded, for a maximum of ten steps after the initial placement of the feet. A missed step, splayed foot, lost balance, or failure to touch heel to toe ended the test. The score was a maximum of ten for each trial and 30 for the test.

Sharpened Romberg (SR): The test subject would stand on both feet in a heel-to-toe posture with arms folded and eyes closed. Upon assuming this posture, he closed his eyes, and timing by test personnel was initiated. The test subject was required to maintain his balance for 60 seconds to complete a trial successfully. A maximum of three trials was administered for scoring purposes unless the subject attained 60 seconds on one trial. The successful completion of 60 seconds on a trial resulted in the assumption that any remaining trials would also score 60. The score for this test was the sum of all three trials in seconds, with a maximum score of 180 possible.

Standing on one leg, eyes closed - right or left leg (SOLEC-R and SOLEC-L): The subject attempts to stand on one leg, with eyes closed, for 30 seconds. Each subject was allowed three trials on each leg, for a maximum score of 90 for SOLEC-R and 90 for SOLEC-L. The test was scored similar to the SR in that the successful completion of a 30-second performance resulted in the assumption that all remaining trials on that leg would also be 30 seconds in length.

Walking on floor, eyes closed (WOFEC): The test, as described, was repeated after SR, SOLEC-R, and SOLEC-L.

During the three- and seven-day tests, the test battery was identical to that outlined except that it was administered each day near the hub while the RTF continued to rotate at 4 rpm. During the three-day rotational period, the subjects performed the test with eyes open. The test subjects performed the test with eyes open during the first few days, then performed with eyes closed during the last four days of the seven-day rotational period. The total test protocol was administered to each test subject upon cessation of rotation for the seven-day test, followed by additional evaluations at two and five hours after cessation of rotation.

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SECTION III
RESULTS

There was a requirement to obtain reliable data relative to the impact of the rotating environment.

The unknown aspects of the severity of this environment were the primary factors that established the relatively stringent test-subject-selection criteria. The predetermined high level of individual fitness minimized the potential for observing cardiovascular abnormalities during the testing. Establishment of normal neurological and psychological values prior to rotation insured maximal value from the psychomotor and operational tasks employed in the study. Further, a relatively good degree of physical fitness was desired so that no task would be compromised because of poor individual work capacity. All test subjects maintained an individual physical-conditioning program after they were selected for the program and never terminated an assigned task during rotational evaluations because of fatigue. A high degree of motivation, cooperativeness, and skill was evidenced by all personnel throughout the program.

Test Subject Selection

The biomedical results presented below include test subject selection, evaluation, calibration, monitoring, and pre- and post-test analytical data. Thirteen persons volunteered from the NR-SD engineering population, the majority of which had prior piloting experience and zero-gravity and/or neutral-buoyancy experience. Some of the basic characteristics of eight of these individuals are presented in table 5. Initial evaluations resulted in the rejection of all but five of the original candidates on the basis of physiological condition. A program of graded exercises for the rejected subjects resulted in the qualification of an additional four individuals. All volunteers successfully passed the stress treadmill test, indicating an absence of cardiovascular abnormalities. The subjects scored high on all psychological tests, particularly in motivation, ascendance, sociality, emotional stability, objectivity, personal relations, and cooperativeness. The individuals qualified as test subjects were then exposed to specific test program training procedures. Test subject E was maintained as a backup crewman while H assumed the responsibility of experiments monitor.

Test Subject Calibration

A major portion of the selection and calibration program for potential test subjects included evaluation of the oculovestibular mechanisms of each individual at the Naval Aerospace Medical Research Laboratories in Pensacola, Florida, by Dr. Graybiel and his staff. Only those who were subsequently used as test subjects are included in table 6, with the exception of H, who participated as the principal experiment monitor. In this capacity, he spent several hours on the RTF during each test period. His profile is specifically included to document an unusual finding and to demonstrate the potential complications associated with the use of an incomplete program of selection and the assumption that a particular test subject is normal. It will be noted that this subject responded in a normal manner to all tests, except that no nystagmus could be elicited by caloric irrigation of the left ear and some low scores were obtained on the postural equilibrium tests. There was some uncertainty relative to normal vestibular function after a failure to respond to the Hallpike test. Subsequent cupulometry verified the lack of semicircular canal function in the left ear. Subsequent X-ray and other diagnostic tests resulted in the determination that this abnormality represented a congenital malformation.

The general fitness of the individuals tested was unremarkable with the exception of test subject B, who had a bad right ankle as a result of a previous fracture; E, who demonstrated some postural problems as a result of an old fracture of the pelvis; and F, who had suffered occasional episodes of tinnitis. Test subjects C and F demonstrated normal hearing, but D had an overall reduction in hearing in the low-normal range. The remaining individuals exhibited mild high-frequency losses, with A demonstrating a severe high-frequency loss.

The threshold caloric tests, with the aid of nystagmus, was performed by the method of McLeod and Meek (ref. 13). All values were within normal range. A modified Hallpike (ref. 14) with subjects' eyes open in the dark was used to determine directional and labyrinthine preponderance. All values were normal except the borderline (23-percent) difference in labyrinthine preponderance in subject G. However, the more significant directional preponderance was within normal limits for this individual. Perception of the oculogyral illusion (OGI) was found to be normal in all individuals. A new variation of the test was used in these analyses, which are to be published shortly (ref. 16). A reliable test of the integrity of otolith function involves a measurement of the maximal amount of ocular counterrolling when a subject is tilted right and left from the upright. The index is defined as one-half the sum of the roll rightward and leftward in minutes of arc (ref. 17). All values are within the normal range. The postural equilibrium test battery depends on the functional integrity of many body systems and reflects the skills acquired in physical activities (ref. 19). All scores were within the normal range or explicable on the basis of previous injury. There was one exception, Subject A made low scores standing on the right leg but a normal score on the left. The two provocative tests for measuring susceptibility to motion sickness were similar in that the stressful accelerations were generated by having the subject rotate his head out of the plane of rotation on the specific rotational device used. The Dial Test (ref. 20) was conducted in the Slow Rotation Room (SRR) with the subjects' eyes open. The Coriolis sickness susceptibility index (CSSI) was measured with the subjects' eyes closed and with use of the chair device. The susceptibility ranged from above average to far below average.

The potential for the occurrence of motion or canal sickness during the testing prompted the screening of test subjects prior to beginning the test series for possible side effects of the selected pharmaceuticals (ref. 7, 23, and 24). Phenergan (25 milligrams) and dextroamphetamine (10 milligrams) were administered orally during a normal routine work day, and the effects were observed for the subsequent 24-hour period. One of the five test subjects evaluated reported the occurrence of a mild insomnia. Therefore, a reduced amount of dextroamphetamine was scheduled in his prescription for anti-motion sickness. Although three episodes of mild emesis occurred during the 12 one-day tests, drug therapy was not required by any of the test subjects. All tasks were performed on schedule and without a reduction in skill. Two occurrences of emesis were experienced by subject C, who demonstrated an above average susceptibility to motion sickness (table 6). However, this individual became more resistant to the rotational stimuli as the series progressed and was able to perform his tasks without distraction from symptomology. Test subject D became nauseated at the end of the day in the last 5 rpm test when he stooped to tie his shoe just inside the crew module door. Stomach awarness was commonly reported by the more susceptible test subjects during early runs of the series and was directly related to the rotational rate.

One-Day Tests - Biomedical Considerations

Biomedical measurements were scheduled pre- and post-rotation to determine the effects of daily stress and fatigue in response to the rotational environment. Results of these evaluations are presented in tables 7 through 9. The blood and urine measurements were discontinued after Test 6 since all rotational rates and configurations had been experienced, and no significant responses were elicited. Except for those changes that are predictable on the basis of increased or decreased work loads, there is a uniform lack of significant change in the majority of the resultant physiological data. The increase in heart rate (table 7) between that obtained in the morning (pre-) in contrast to that obtained in the evening (post-) following the test is probably more related to the increased activity related to post-flight testing than to either fatigue or other stimulus. This conclusion is further validated by a consistent lack of change in blood pressure. The modest change in body weight, representing the change over a one-week period, could not be specifically attributed to the test program in this study. The low heart rates exhibited during passive radial transfer (table 8) are attributed to the fact that the test subject was lying down. It will be noted that there were no consistent differences in heart rates because of rotational rates, ascent-descent, or test-subject orientation. Subjective comments indicated that the response to this test varied from neutral to pleasurable and was completely without stress. It was observed that the illusion of standing was very strong during transfer to the longest radius during the 4 and 5 rpm tests. It was reported that the illusion of traveling on a curve was also strong at these higher rotational rates. Heart rates obtained during ladder climbing and tangential locomotion were excessively variable and did not provide valid comparative data.

The recorded chronic heart rate data, obtained by means of the EKG telemetry system, was examined with respect to those events in which such variables as programmed activity and procedures remained relatively constant (table 9). These analyses primarily include movement between stations and the performance of DRT tests at the hub and 30-foot and 78-foot stations. It should be noted that locomotion from one station to another results in an orientation that is significantly different from that which would apply in a space station. These data are presented for the sake of academic interest and as indications of total stress. The mean heart rate for station changes to the hub and from the hub indicated that the descent from the hub requires less effort than changes toward the hub. This observation may be partially explainable on the basis of physical loading resulting from the gravity gradients at the different radii. The heart rates obtained during the post-test ataxia analyses reflect the work involved in the test and were unaffected by the prior rotational rate experienced in the one-day exposures. No significant differences in heart rate were found during DRT operations with respect to station location.

The electrocardiographic wave forms appeared essentially normal for all subjects. Some arrythmia activity was observed in test subject C during the testing, and subsequent clinical evaluation resulted in the temporary suspension of this individual as an active test subject after the one-day test series.

Three-Day Test

This test resulted from the abort of the first attempt to conduct the seven-day test program. The abort resulted from a complete and irreversible power loss on the rotational beam. Blood pressures, which were recorded three times per day, did not vary from individual normals as observed during test subject selection on the one-day tests. Pulse rate showed a tendency to be slightly elevated, but no definite trend was noted during this period (table 10). The mean heart rate for all test subjects while operating the DRT was 82 beats per minute. The changes in heart rate associated with station changes did not vary significantly from that observed in the one-day tests (table 9). Testing of visual acuity with the orthorater revealed an interesting tendency toward exophoria. It was strongest on the first day of the test period and diminished over the three-day period. Pre- and post-clinical tests were unremarkable, and the test subjects were found to be in outstanding health.

Seven-Day Test

Three test subjects who had participated in the three-day test and one who had participated in the one-day test comprised the crew for the seven-day evaluation. Outstanding motivation, cooperativeness, and compatibility was demonstrated by all members of the crew. A temporary loss of power during the evening of the first test day threatened the emotional stability of the crew. The sump pump failed and sewage backed up into the shower stall. The bad odors were suffered for approximately eight hours, resulting in loss of appetite and motivation. The pump motor was rewired early on the second day, and morale returned to a high level by midafternoon. The remaining days of the test were uneventful with respect to facility operation, and data collection from all tests scheduled in the program was highly successful.

Three of the subjects had slight weight gains over the seven-day period, and one subject had a weight loss of two and one-half pounds. There was no significant change in blood pressures or heart rates between the pre- and post-test values, not did the blood pressures and heart rates obtained daily during the test reveal any significant response to the environment.

Figures 17 and 18 present the responses of the individual test subjects to the orthostatic tolerance test of a ten-minute tilt at 90 degrees. The significant difference in response relative to pulse pressure in test subject A is believed to be related to emotional upset on the last day of the test and totally unrelated to the rotational environment. The emotional involvement was related to the medically critical condition of his father. The anticipated improvement in orthostatic tolerance and work capacity because of the increased gravitational loading was not found in the post-test evaluations. The evaluation of work capacity (fig. 19 through 22) yielded results well within the normal variations seen from one day to the next in individuals with the exception of subject G. No explanation for this apparent improvement in pulse pressure can be hypothesized at this time. The mean values for metabolic response to the ergometric evaluation, obtained during the last minute (tenth) of the test, are presented in table 11. As noted, little change was recorded in either blood pressure or heart rate in two of the test subjects, with two exhibiting slight increases during the post-run evaluations. Differences in oxygen

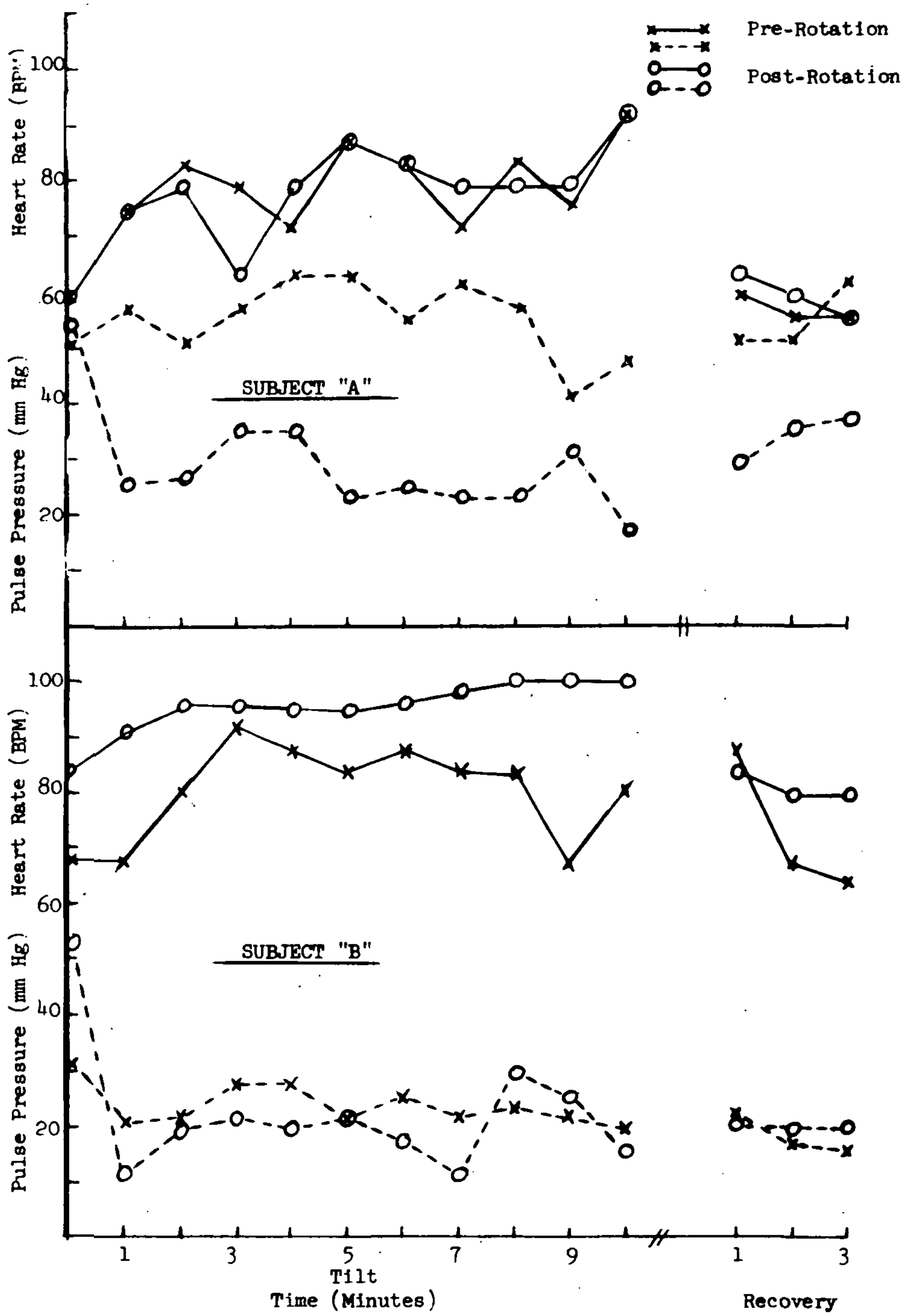

Figure 17. 1. Orthostatic Tolerance

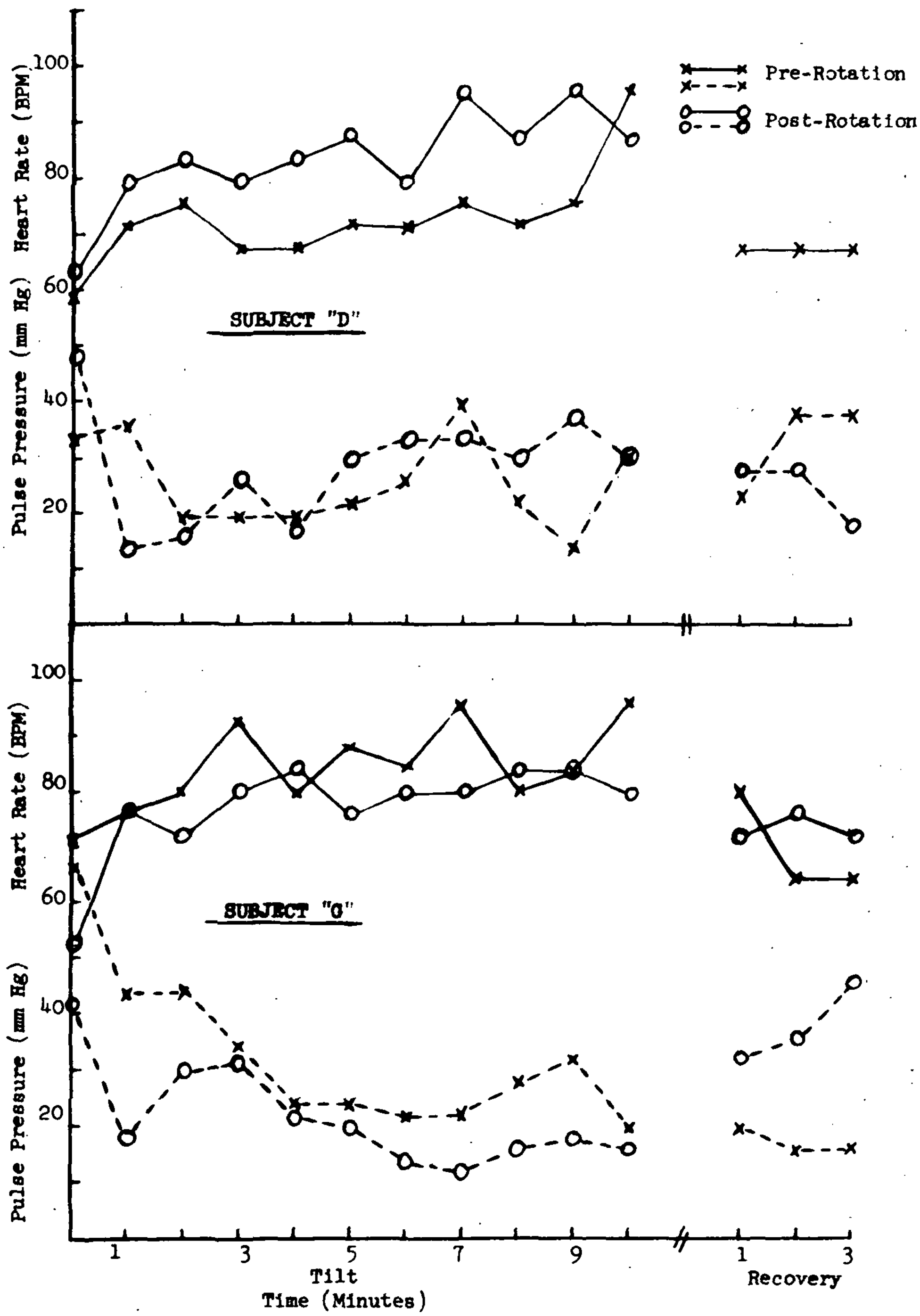

Figure 18. 2. Orthostatic Tolerance

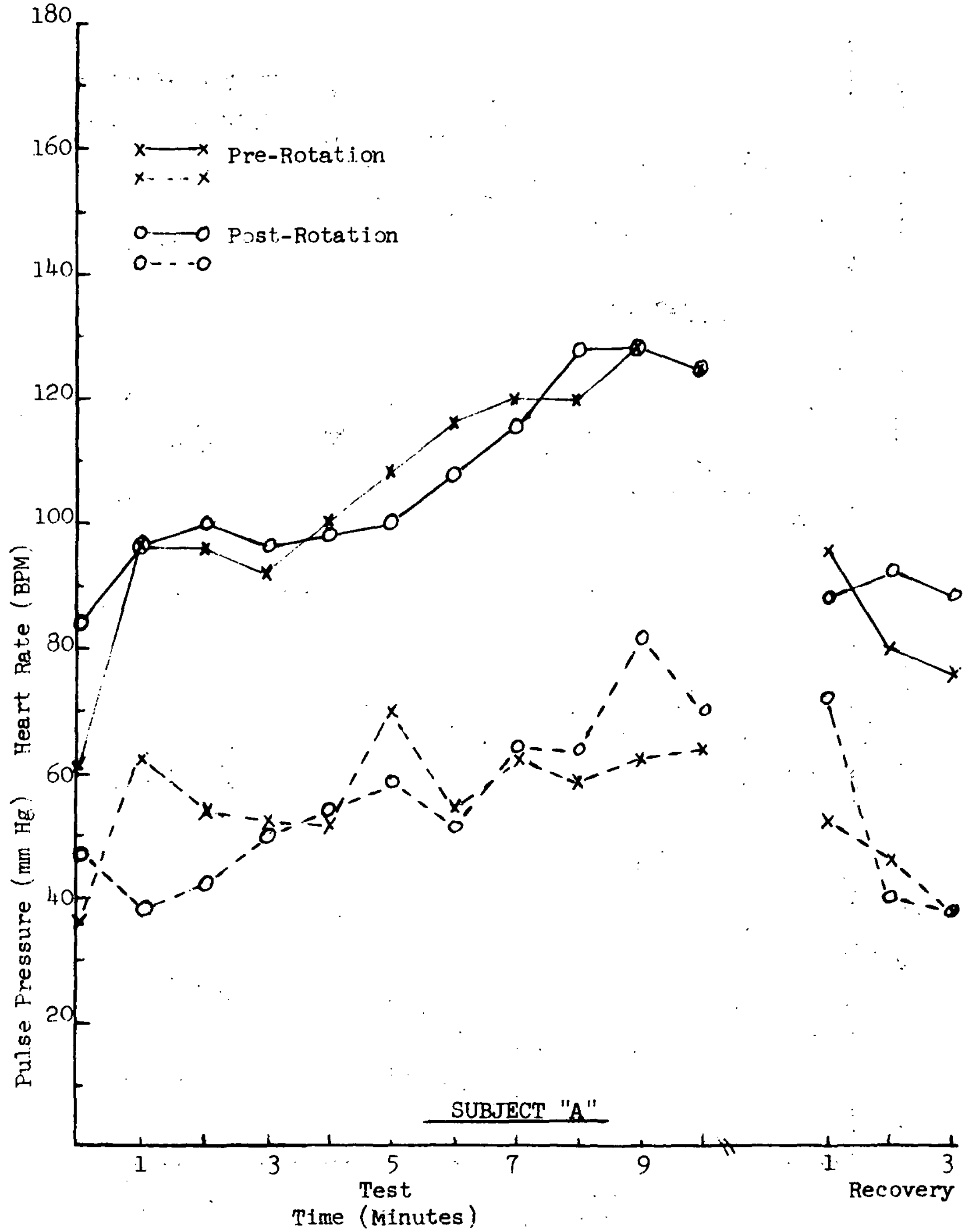

Figure 19. 3. Bicycle Ergometry

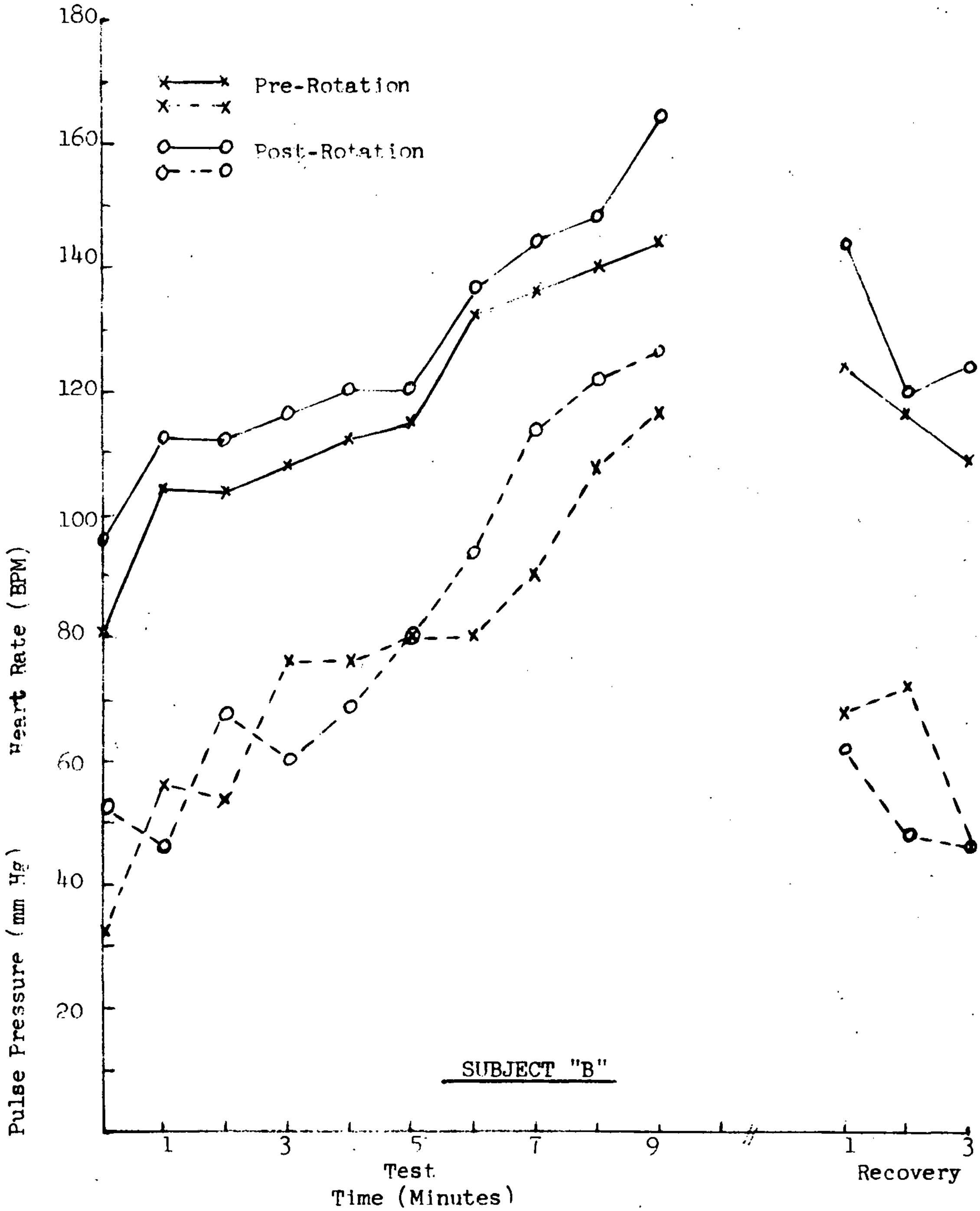

Figure 20. 4. Bicycle Ergometry

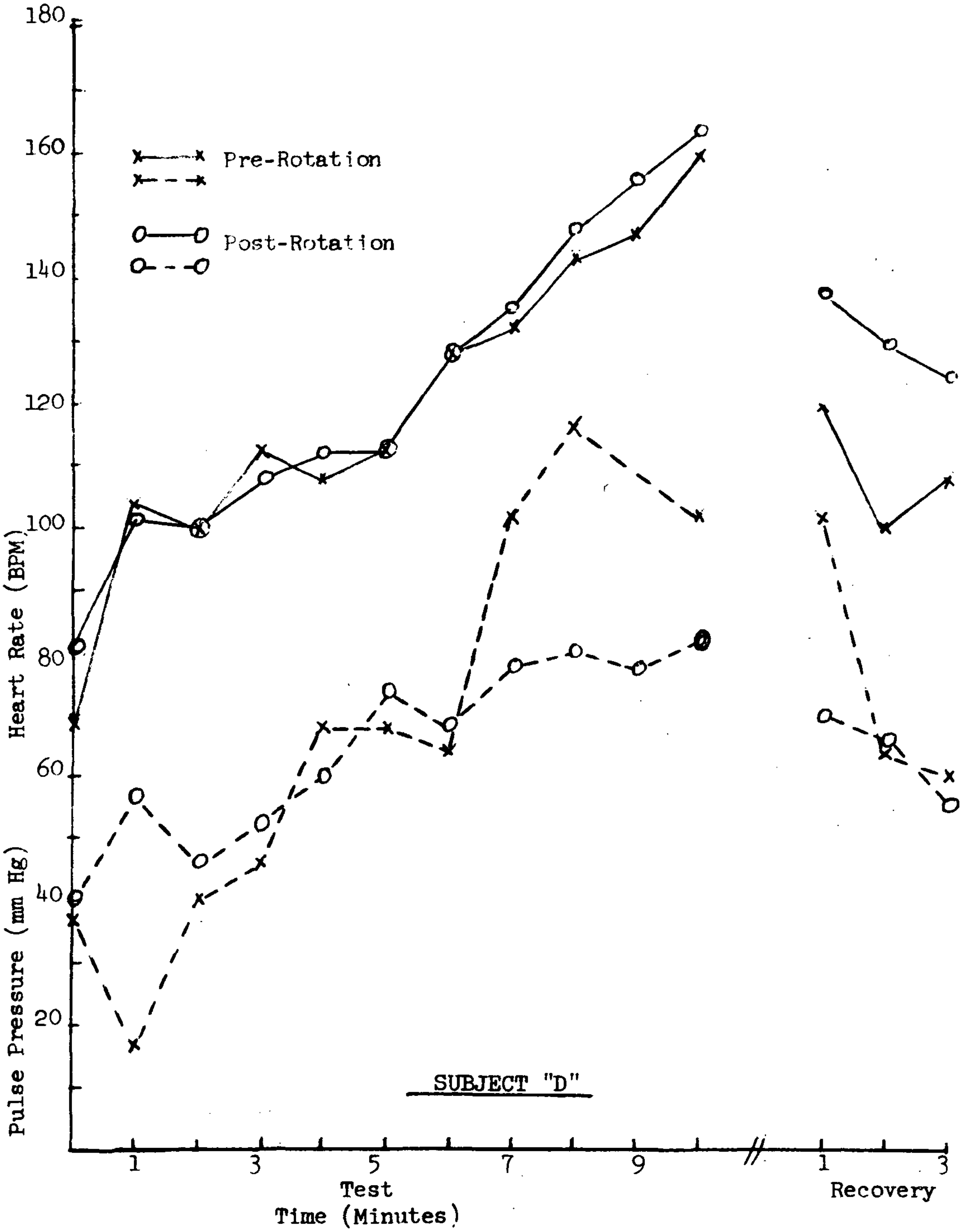

Figure 21. 5. Bicycle Ergometry

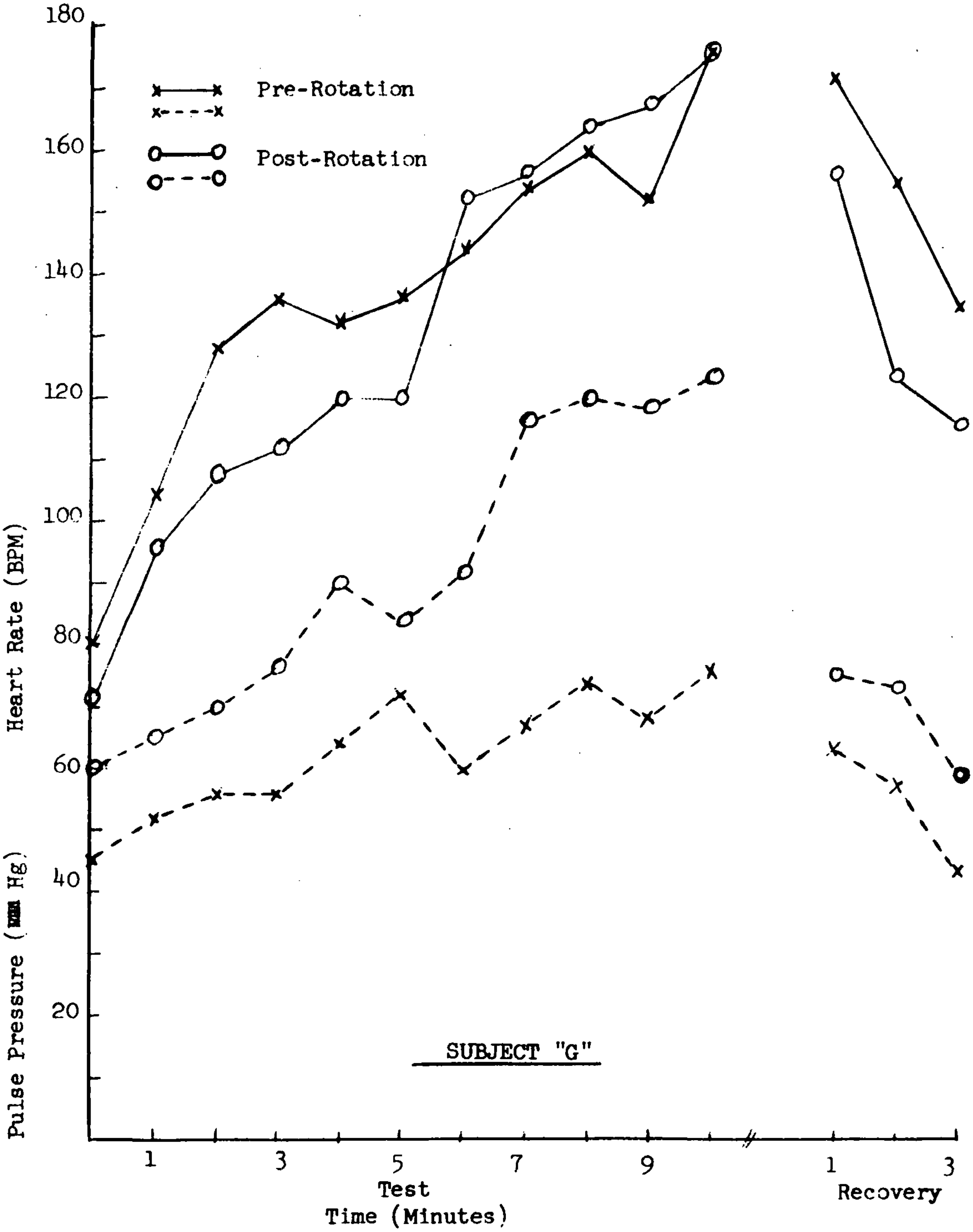

Figure 22. 6. Bicycle Ergometry

consumption and respiratory quotient were within experimental error and probably insignificant. Carbon dioxide values were unremarkable. The differences reflected only exercise hyperpnea. Pulmonary function analyses also demonstrated minimal changes (table 12).

Vision testing was accomplished as in the previous three-day run. Parameters measured included far vision, near vision, vertical phoria, horizontal phoria, visual acuity, and depth perception. All visual values were unremarkable with the exception of horizontal phoria. It showed a uniform tendency toward exophoria early in the test, a tendency toward esophoria during the third and fourth days, with values at the end of seven days tending to be mixed (table 13). This finding should be further evaluated in future rotational studies.

No serious clinical problems were noted during the testing. One subject developed a nonspecific upper respiratory infection. It did not result in an elevated body temperature, but produced a mild malaise, rhinitis, pharyngitis, and temporary loss of eustatian tube patency. Symptomology subsided within two days following treatment. Mild dermal ulceration occurred on some test subjects at the site of EKG electrode placement on the fifth day, requiring the relocation of the electrodes. Ulceration was controlled rapidly with the application of antibiotic ointment. Hematology and blood chemistries (table 14), were evaluated pre- and post-rotation and were basically unremarkable in that all values fell within the normal range.

Post-rotation clinical evaluations consisting of eye, ear, nose, and throat and chest examinations were unremarkable, except that the test subject who exhibited the upper respiratory symptomology during the test phase retained some lymphatic hypertrophy, with right tympanic membrane injection. Nystagmus, induced by head motion, was most pronounced to the right of this individual. Two subjects showed left nystagmic predominance, and the fourth demonstrated a bilateral nystagmus of equal intensity.

Samples of EEG traces are presented in figure 23. Sleep patterns were not obtained, and EEG specialists detected no modifications of wave activity in response to the rotational environment.

General

Although formal caloric measurement or nutritional control was not obtained during the program, general food habits were notable and are of interest relative to the implications for future long-term orbital vehicles. The one-day tests of this program were initially approached by the test subjects with a certain amount of caution from a dietary standpoint. This was because

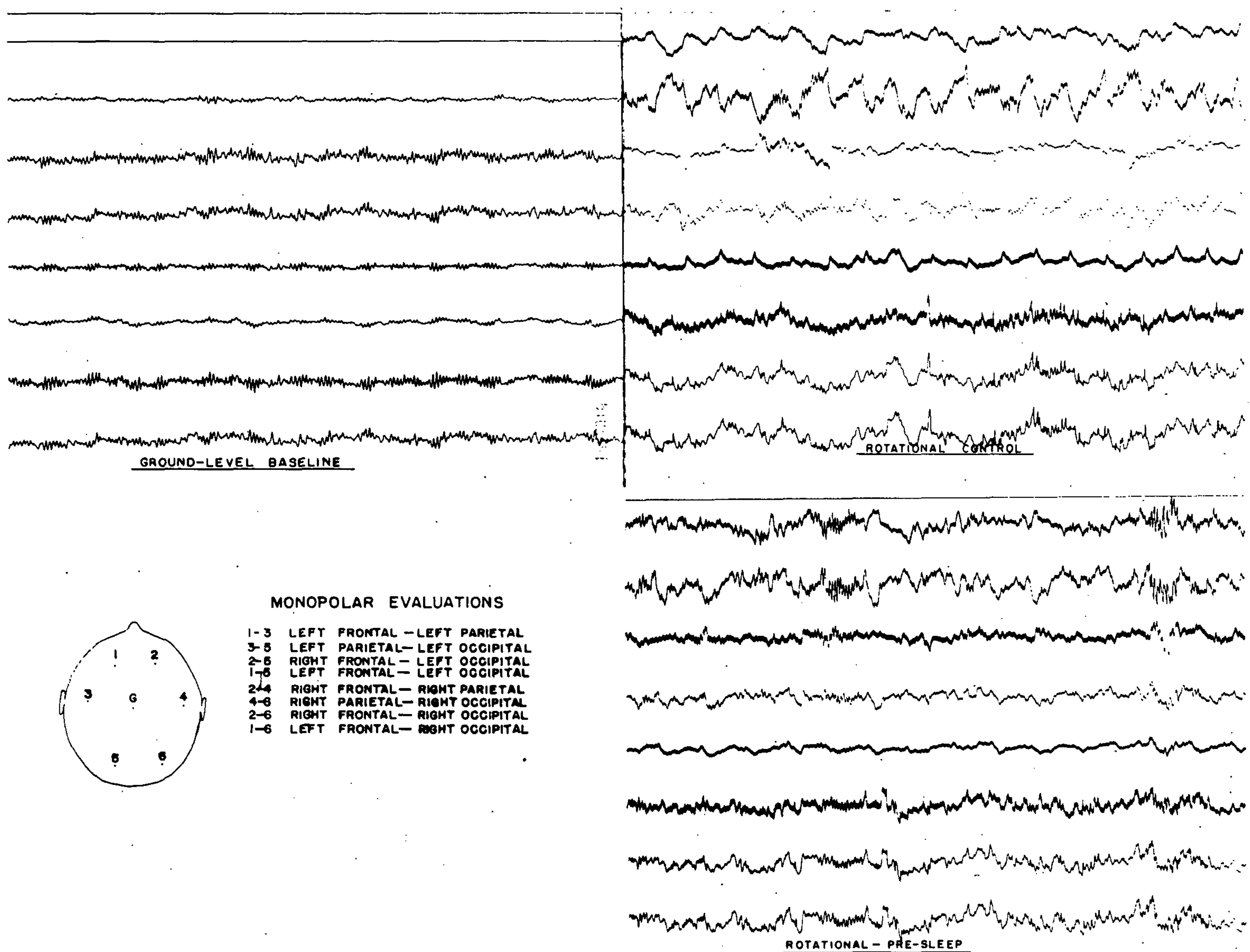

Figure 23. EEG Lead Configurations

of the predicted problems of gastric instability or potential episodes of overt motion sickness in the rotating environment. These precautions were found to be unnecessary for this test crew. Hearty sandwich lunches became a high point in the day during the one-day test series. The test subject personnel reported that they felt more comfortable with a full stomach than an empty one. Beverages were provided in the crew module of the facility each morning, without restriction. These initially consisted of homogenized milk, chocolate milk, and carbonated and noncarbonated soft drinks. Group preferences rapidly reduced this inventory to chocolate milk and noncarbonated soft drinks.

Food preparation and stowage capabilities in the crew module limited the types of food that could be used for the multiday tests. However, a large freezer, limited refrigerator space, and portable electrical appliances were available. The inventory of the latter included an electrical fry pan, warmer oven, and broiler.

Extensive fat frying was prohibited because of fire and smoke hazard. However, bacon was frequently prepared for breakfast. Food was purchased from a local supermarket. Basically it consisted of frozen foods, canned soups, sauces, and other quickly prepared items. The menu was based on the personal preferences of the crew, but also was designed to provide the basic nutritional needs. Regularly scheduled meals became the high points of the day, and snack food items also were enjoyed by the test subjects during the day and evening. Breakfast typically consisted of juice, bacon and eggs, waffles, or coffee cake with either tea or coffee. Lunches consisted of luncheon meat, sandwiches and milk. Dinners, included soup, frozen meat dishes, fresh salads, frozen vegetables, ice cream, cookies, or other dessert.

Baseline Data

The baseline data collected on the various psychomotor test devices are presented in tables 15 through 23. These data were collected during the training before and after various periods of rotation. In as much as these data are used in the test analyses, no statistical evaluations were attempted of the pre-rotation and post-rotation data. Purposes of the training and testing were to raise the performance of each test subject to a skill plateau prior to rotation, to familiarize the subjects with the tasks and proper methods of performance, and to acquaint each with the overall test objectives.

Langley complex coordinator device (LCC). - The first four test subjects (A, B, C, and D) were placed on formal training approximately six weeks before the beginning of the rotational evaluations. Approximately two weeks before the formal testing, training was initiated on the RTF. During training, each subject performed 20 cycles (1000 problems) each day on the

LCC (table 15). The test subjects were instructed to concentrate on reducing the total time per set of 50 problems and to establish the smallest interval time (IT) possible to maintain errors below 25. For the three- and seven-day test program, test subjects F and G were added to the test crew and placed in training and their baseline data collected as described. Before the three- and seven-day tests, the experienced subjects reduced the number of trials to ten cycles to prevent overtraining effects.

Decision reaction time device (DRT). - All test subjects performed 12 cycles (30 problems) on the DRT during the training period. All training was conducted in the standard mode (STD) for the one-day tests, while training included ten cycles of continuous code change (CCC) and two minutes of the continuous run mode (CR) per day during the training for the three- and seven-day tests, with four cycles per day of alternating displays mode (AD) on the two days before the actual testing (tables 16 and 17).

Standard Stromberg (STROM). - The data presented in table 18 are the means of six trials per day per test subject. The test subjects worked in pairs, with one subject performing the task, while the alternate recorded time and errors. The objective established for this test was to determine the lowest possible performance time.

Modified Stromberg (MOD. STROM). - The data presented in table 19 represent the mean values of three trials per day during the training period and during the pre- and post-test measurements. This test was performed at the hub station only during the test. Training on this test was begun after the subjects had become proficient on the STROM, and a significant carryover of skill was apparent in the first week scores. The lack of response to this task resulted in the elimination of it from the three- and seven-day test programs to permit additional DRT tasks.

Pursuit rotor (PR). - The data presented in table 20 represent the evaluations of PR performance. The test subjects performed three groups of three 20-second trials (nine total) each day during the week prior to test. The data presented herein represent results of tests performed with the table turning at 60 rpm. The time was recorded for each trial and averaged for the score.

Mental arithmetic (MA). - The data presented in table 21 represent the modal correct answers for the MA task. Each test subject performed one trial of ten problems per day during the week prior to the beginning of the rotational test. Each subject used all six training tapes prior to the rotational test programs.

Memory drum (MD). - The MD task training-baseline data are presented in table 22. Each subject performed one trial of ten trigrams each day during the week prior to the rotational tests. Both answers and performance times were recorded. The mean correct answers for the first four trials are presented in table 22A. The mean correct answers for all correct trials are presented in 22B.

Postural equilibrium (Ataxia). - The ataxia tests were administered to each test subject every day in the last week prior to the rotational exposure (table 23). Perfect scores are as follows: for the WOFEC, 30, SR, 180, and SOLEC, 90. The consistently low score for SOLEC-R for test subject B was because of an old ankle fracture. There were no obvious postural inadequacies in the remaining test subjects, nor can explanation be provided for periodic low scores.

Psychomotor data recording and analysis. - Data during the rotational evaluations were recorded by test subjects working on the buddy system, by experiments monitors, and by automatic recording equipment. The only data requiring reduction before submittal for computer analysis were the extensive DRT recordings. They were manually reduced to tabulated data. Data analyses included statistical evaluation of objective data and summarization of various subjective observations reported during daily debriefings. The objective test data were subjected to an analysis of variance (ANOV) utilizing an IBM general program for the 360 computer as described by Hartley (ref. 25).

The raw data were arranged in a matrix format representing the experimental design utilized, with scores placed in cells to obtain sums, means, and number for factors and levels, such as S_1, S_2, S_3, S_4, A_1, A_2, ..., 0_1, 0_2, ..., etc., representing subject number, station number, orientation number, etc. From this matrix the data were coded for the computer program. The program provided the sum of the squares, degrees of freedom, mean squares, and grand mean. The user determined which mean squares must be pooled or used singularly to compute the F ratios. This required consideration of the type of experimental design being utilized, the nature of the data, and the assumptions associated with the statistical analyses. The basic experimental design used the evaluation of Subject X Treatments, as discussed by Lindquist (ref. 22). This experimental design is intended to eliminate intersubject differences as a source of experimental error. In this design, each subject received all treatments relative to the various factors or variables. The order of treatment was varied to avoid interaction of order effects. This technique was chosen because it is especially useful and effective when the number of subjects is small.

Because the experiments used in this program were exploratory, the subject population was small, and the number of trials few, levels of significance were set at 0.2 and 0.1 or less and are included in the ANOV summary table. Interpretations must be developed cautiously, and similar results in alternate tests were required to elicit a conclusion. In instances where a significance of 0.05 or less was obtained for a variable, additional analyses of the means were performed. The Newman-Kuels procedure (ref. 26) was used for the analysis of the means. This procedure allows comparison between levels of a variable to determine which mean differences are statistically significant. In addition, the pre- and post-test baselines were compared with rotational performance. For these analyses, the baseline scores were corrected to represent an equal "n" with the experimental data in that the sum of cells rather than means is compared. This procedure tends to make the critical differences between means somewhat greater and the results of the test more conservative in the indication of significant differences. A typical Newman-Kuels table (table 24) has the factor (R = replication) arranged by level from "post" through R_1 in increasing value. The cell values are the difference between the factor on the left and the corresponding horizontal factor. Thus, in the referenced table, the value in the first-row second column represents the difference between the sum of cells for the fourth trial (R_4) and the post-test baseline corrected for equal number of trials. The Newman-Kuels procedure provides a critical difference for the various levels of statistical significance for the different steps apart. The term steps apart refers to the arrangement of the means in increasing value, with the asterisks indicating the levels of significance for those cases where critical differences occurred. If the F-ratio probability exceeded 0.05, a Newman-Kuels analysis was performed of factors with values greater than two means and was performed regardless of F-ratio probability for pre- and post-test baseline comparisons.

Langley complex coordinator (LCC). - Results of the LCC evaluations analyses are presented in tables 24 through 30. The major experimental variables in the one-day tests included the four test subjects (S), three rotational rates (A), three orientations (0), and time of day. The rates were scheduled to provide four replications (R) at each rate, varied equally between morning and afternoon. The orientation included facing the pro-spin, anti-spin, and radial (toward the hub) directions. During the three- and seven-day tests, the rate was a constant (4 rpm), but head movements (A or H) were added to increase the task complexity, with blocks of days (B) evaluated during the seven-day tests.

The greatest number of variables was used in the one-day tests (tables 24 and 25). Although a significance of 0.2 was indicated in the analysis of variance for rotational rate, while the mean performance increased as the rotational rate increased, conclusions must remain tentative relative to rotational rate on performance at this time. No significance was found in the three orientations used. This was in contrast to the subjective comments of the test subjects. Such things as light glare and foot slippage were reported to have caused poor performance in some orientations. The best orientation on the basis of subjective performance did not result in a universal opinion. The difficulty with foot controls led to the opinion that foot controls are not desirable in the rotating environment. This observation requires further evaluation. Analyses of the four replications during the one-day tests was highly significant in the analysis of variance. These differences were further compared with the pre- and post-test baselines (table 24). The analyses indicated that the pre-test scores were better than the initial performance on the RTF, performance time consistently decreased during the 12 days of testing, and that the post-test performance was better. The rotational environment had an initial negative effect on LCC performance, with a combination of learning and accommodation to the environment occurring during repeated exposures. The interaction of the rotational rate and replications (AR) was found to be highly significant (0.005), but upon closer examination was found to be predominantly related to poor performance during the first 5 rpm exposure.

The analysis of variance for the three-day tests on the LCC did not indicate any significant findings except for an interaction of head movements and replications (table 27). Examination of the data indicated that the first two trials after ten head movements were slower than the next two. This did not occur after five head movements. These data are contrary to the opinions of two subjects, who reported that "performance seemed to be better immediately following head movements, with a latent negative effect." The negative effect of the rotating environment on the initial performance during the one-day tests was not observed during the three-day exposure. There were no significant findings in the seven-day test (tables 29 and 30). There were no significant differences between pre- and post-test baselines and performance during rotation for the three- and seven-day tests. This finding is contrary to the results of the one-day tests and may be indicative of long-term adaptation.

Decision response time device (DRT). - The DRT experiments permitted the analyses of two performance criteria: total responses and total time. Other discrete measurements were recorded but were not evaluated statistically in this study. The total responses reflect the number of switch closures used to cancel 25 stimulus lights (the number of incorrect switches activated indicates errors). During the one-day tests, two analyses were made of both criteria; the first on the 30-foot and 78-foot stations only considering couch orientations (tables 31 through 36) and the second at all stations with the data pooled for orientations (tables 37 through 39). The complete factorial design for the first analyses included six factors: four test subjects (S), two times of day (T) and two stations (A), three rotational rates (V), two replications (R), and five orientations (0). Comparisons were made with respect to rotational performance and the pre- and post-test baselines. The analyses of all stations included the hub station in the evaluations (tables 37 and 39). The station orientation of the 30- and 78-foot locations was pooled. During the one-day tests, only the standard mode (STD) was used. The analyses of variance indicated that performance was faster in the morning than in the afternoon, leading to a conclusion that fatigue affects performance. Since it is not possible to compare the performance in the rotational environment with the non-rotational environment, further conclusions are not possible. Observations with respect to fatigue are complicated by the "greater than one g" created within the gravitational field of the earth. Although the F ratio for time of day, utilizing total responses, is significant at the 0.2 level, it should be interpreted cautiously since it indicates a greater number of errors in the morning. The analyses indicated that performance time in the 78-foot station was superior to that in the 30-foot station (0.1), with no significant difference for total responses (or errors). Considering all stations, the performance time F ratio was 0.2, with the mean performances for the three stations lowest at the hub. This particular variable was used for pre- and post-test performance comparisons. However, pre-test data were obtained at the hub only, while post-test evaluations were performed at the hub and 30-foot station. Considering performance time, the N-K analyses indicate that post-test baselines for both the hub and 30-foot station differ significantly from each other, as expected because of orientation, and the other performances at the work stations and the pre-test hub performance (tables 23, 36, and 39). In the analysis of variance for the 30- and 78-foot stations only, the pre-test baseline at the hub differs significantly from the test performance at the 78-foot station and the analysis of all stations (table 37). The hub performance differs from the pre-test baselines obtained at the hub. The conclusions relative to the better performance during post-rotation evaluations must be tempered by the fact that there was significance between replications, indicating that both learning and accommodation to the environment occurred during the one-day tests. Therefore, no positive conclusions are possible about the general decrement in performance in response to the rotational environment. However, the significant difference anticipated between performance at the hub and the 30-foot station is indicative of a true difference between the stations. This finding also provides a basis for questioning any interpretation of performance results between the stations as being responsive to the rotational environment. Further verification of all positive results is required, including a more comprehensive baseline evaluation at all stations in future tests. The N-K analysis, utilizing total responses as the criteria for the 30- and 78-foot stations only, compared to pre- and post-test baselines, indicated the following groupings of mean performances: 78-foot +30-foot stations; pre-test; and post-rotation hub + post-rotation 30-foot station. These groupings indicate that total errors were lower during rotation, possibly reflecting differences in motivation.

explain this result further. However, it should be noted that while the performance was significantly different in the anti-spin direction only, the mean performance time was progressively greater from the pro-spin through orientations to the anti-spin position. This observation was also noted during the one-day tests. With total responses used as the criteria, significant results were obtained for replications considering all stations (table 69) but were not evident when the 30- and 78-foot-station analysis of variance was considered (table 63), indicating that more errors were committed during the early exposures to the various test combinations. The data also indicated that more errors were committed at the 78-foot than at the 30-foot station.

Detailed analyses of the CR mode during the three-day test (tables 48 through 51) indicated that a significantly greater number of errors was committed during the second run than the first. The F ratio of a 0.2 probability for test days (table 48) justified examination of the mean performance of each day. These indicated an increasing trend toward more errors as the test progressed. This was not observed during the seven-day test. The N-K analyses did not indicate a significant difference in comparing pre-test baseline with test-days data. The analysis of performance time during the seven-day test (tables 75 through 78) indicated significant results for blocks of test days and work stations. On the other hand, the anticipated difference between the first and second two-minute set, as a result of fatigue, did not develop. Further, analysis of blocks of test days, compared with pre-test performance, indicated only that performance during the first two test days was lower than during the last two test days, but that no other differences were evident. This finding supported other evidence of performance improvement during the tests. The comparison of performance at all three work stations revealed that all differed significantly from each other, with the fastest performance being at the hub and the slowest at the 78-foot station. The analyses of total response (tables 79 and 80) yielded no significant results.

The analysis of performance time for the alternating display mode during the three-day test revealed significant differences for work stations (A), test days (B), and replications (R) (tables 52 through 56 and 81 through 86). The F-ratio probability for work stations, although only 0.1, indicated that performance was faster at the 30-foot station. Comparisons of the test days and the pre-test performance determined that performance on the first test day was slower than the other two test days and the pre-test baseline. This represents additional evidence for adaptation during this test, indicating that it occurs to a great degree by the second day. The final finding was that performance tended to improve through the four trials, indicating a possible positive result of the head movements during the performance of the task. The analyses of total responses revealed only that fewer errors were made at the 30-foot station, which corresponded to the faster performance there. No other significant results were obtained.

The analyses of orientations were significant at the 0.2 level, but require cautious interpretation. The mean performance times at each orientation increased from pro-spin to the anti-spin position. Other variables in the table are significant. One is the interaction of the results from the first 5 rpm exposure.

The DRT devices were modified for the three- and seven-day tests to provide continuous code changes (CCC), continuous running (CR) for two-minute periods, alternating displays (AD), as well as the standard (STD) mode. There were no significant data from the variables evaluated during the three-day test between the rotational values and the pre-test baselines (tables 40 through 55) except for replications during the CR mode (table 48), subjects, and days during the AD mode (tables 52 and 56). During the seven-day tests, significance was demonstrated for blocks of test days (B) for all modes. The N-K analyses indicated that mean performance decreased for the first two days but had surpassed the pre-rotation base lines by days 6 and 7. From this it is possible to conclude that adaptation to the rotational environment does occur, requiring at least two days, and that learning and adaptation continues over a seven-day period. For the STD mode, as in the one-day tests, performance was significantly better at the hub than the other stations (tables 57 through 62). The slowest mean performance time having a significance of at least 0.2 was obtained in the anti-spin orientation. No other meaningful results were obtained except for various interactions for which no interpretations are possible at this time. In the evaluation of total responses, it was indicated that total errors decreased in the rotating environment over baseline data, possibly reflecting motivation.

The CCC mode produced no significant differences during the three-day test , but indicated significance during the seven-day test in performance time with respect to blocks of test days (B), orientations (0), and replications (R). No significant differences were obtained from work stations (tables 63 through 74). B was significant in the analysis of variance for the 30- and 78-foot stations (tables 63 and 68) and for the data comparing all stations (tables 69 and 74). The N-K analyses indicated the following groupings of means for 30- and 78-foot stations only: days 6 and 7, days 3, 4, and 5; pre-test and days 1 and 2; for all stations, and days 3, 4, and 5 and days 6 and 7; and pre-test and days 1 and 2. These groupings indicate that learning and adaptation occurs after the first two days. The data do not statistically support the concept that the rotational environment has an initial negative effect on performance, even though the pre-test and days 1 and 2 tend to that direction. The significant results for replications (table 74) support the observations for blocks of days in that the first performances of the tasks during rotation were slower than subsequent performances. Results for orientations produced significantly lower task performance in the anti-spin orientation (table 68). Examination of the data for the several interactions of orientation with other factors did not

not represent a concerted effort to perform well, which is so necessary, according to the test subjects, to obtain fast performance times on the STROM.

The analysis of STROM test results during the seven-day test revealed that performance without head movements was slower than that following five or ten head movements (tables 99 through 102). This observation corresponds to results seen in the three-day test, but is subject to the same criticism and caution. The subjective comments relative to this test were related to the amount of energy required. All subjects reported that considerable effort was required to maintain fast times. Another consistent comment stated that once an error was made, recovery was more difficult than in the non-rotating environment.

The complete factorial design for the Modified Stromberg included four subjects, three rotation rates, two times of day, and two task replications. Cell entries in the factorial design are the means of the trials on a given day. This test, performed during the one-day tests only, yielded no significant results for the analyses of variance of the rotational performance data (tables 103 and 104). The N-K analysis (table 105) indicated that the post-test baseline was significantly faster than either the pre-test or rotational performances. From this observation, it is possible to conclude that the rotating environment did have a negative effect on task performance although differences in rate made no significant differences. The a.m. performance was, as expected, better than p.m. No other significant results were obtained.

Pursuit rotor (PR). - The completed factorial included four subjects, three head movements, and three replications. The cell entries were either the mean of one set or the average of as many as three sets where conditions were repeated. Results from the three-day test indicated that there were differences in performances for different numbers of head movements (tables 106 and 107). The N-K analysis revealed that a significant difference existed from the pre-test performance to better performance while rotating, indicative of continuing learning (table 108). The differences in head movements, as reflected by a F-ratio probability of 0.1, may be attributable to the improved performance after five head movements as contrasted to either ten or none, in that order. This represents additional evidence for the beneficial aspects of head motions upon the adaptation process. During the seven-day rotational period, this test revealed a gradual improvement with respect to blocks of days (B) from the pre-test performance throughout the test (table 109 through 111). Again, as in the three-day test, the F-ratio probability of 0.2 pointed toward differences among mean performances with varying head movements. Those means supported the conclusion that head movements assist in adaptation. This test suffered from difficulties with the equipment, which produced questionable scores on some days. Some attempt was made to

The analyses of performance time for the seven-day test revealed that blocks of test days (B), work stations (A), and replications were significant (table 87 through 89). Comparison of B revealed that the first two days were significantly slower than balance of the test days. This finding supported similar results in the one- and three-day tests, indicating the progression of learning and/or adaptation. The differences between A indicated that performance was faster at the 30-foot station. This finding supported results obtained during the three-day test. The results of comparison between R also supported similar results obtained during the three-day test. No significant results were obtained for total responses (tables 90 and 91).

Stromberg dexterity tests (STROM). - The complete factorial design of this test included four subjects, three rotational rates, three orientations, two times a day and two replications during the one-day tests. The cell entries represented the mean of both of the STROM test sequences. The analyses included evaluation of the pre- and post-test baselines with subject performance and the various rotational rates. For the three- and seven-day tests, the complete factorial design included four subjects, five test conditions, and two replications. The cell entries are means of two trial performances or, in some cases of excluded data, one trial performance.

The analysis of variance during the one-day tests revealed that there was a difference in performance caused by the rotation rates (tables 92 and 93). The N-K analysis, which also compared pre- and post-test baselines with performance at the three rotation rates, determined that 5 rpm performance is significantly slower than at 3 and 4 rpm, which are not significantly different; and second, the pre- and post-test performance is comparable to, but is significantly faster than, each of the rotation rates (tables 94 and 95). Two observations are possible from these findings. First, the rotating environment has a negative affect on tasks that require gross body motions and second, that the increased Coriolis forces and cross-coupled angular accelerations produced with the increased rotation rates correspondingly affect performance. For the three orientations evaluated in this test, results indicate that performance at pro-spin is slower than at axial and at anti-spin. Contrary to expectations and other test results, the F-ratio probability of 0.2 for time of day indicates that performance is better in the p.m. than in the a.m. This result would require additional verification before acceptance. The replication of performance tasks is in the expected direction of improved performance for the second trials, indicating a task warmup effect. The results of the three-day STROM tests indicate that performance while rotating, without preceding head movements, was slower than trials with preceding head movements (tables 96 through 98). This is evidence of a positive effect of head movements. However, caution is advised because the trials on which the results were based were erroneously termed warmup instead of baseline, as had been originally planned. Thus, it is possible that the performance does allow for this during the analyses. Further, the test subjects became so proficient, even at the maximum of 60 rpm for the turntable, that they were continually approaching perfect scores. This reduced differences in performances throughout the test.

Memory drum (MD). - The existence of two performance criteria permitted the conduct of two experimental analyses. Both analyses were complete factorials, with four subjects, and four treatments, pre-test baseline, rotation with no head movements, rotation with head movements, and post-test baselines. The cell entries were either single scores or means of repeated performances under similar conditions. No significant results were obtained during the three-day test (tables 112 through 115). However, during the seven-day rotational period, this test yielded an F-ratio probability of 0.2 relative to head movements (H) (tables 116 through 119). Examination of mean performances revealed that for both criteria, i.e., performance and H, performance was poorer with no head movements as opposed to head movements. This result supported some subjective comments that indicated that head movements were positive in their effect upon performance. The low statistical significance requires that further evaluations be performed before definite conclusions are formed. However, this particular test did not reflect any short-term memory losses in response to rotation as had been reported subjectively. This observation was based upon the observation of what appeared to be excessive confusion and inability to remember small task details. The evaluation of recall, utilizing the MD, was a cursory examination requiring further sophistication, increased experimental controls, and validation prior to more definitive conclusions being made. One observation, by the test subjects having the greater difficulty with the task, was that it produced some anxiety when success was not as rapid as expected.

Mental arithmetic (MA). - The complete factorial design included four subjects (S), three head movements (H), and two replications (R). The two replications were the first set (three problems) and the second set (next three problems) evaluated under the various conditions. The cell entries are single set scores or means of sets for those repeated conditions. Planned analyses included comparisons of pre-test baseline with performance following the various sets of head movements. The only significant result obtained during the three-day rotational period was a difference of 0.1 among the number of head movements (tables 120 and 121). Inspection of the mean performances revealed that the best performance was obtained after ten head movements. Worst performance followed no head movements. This is additional supportive evidence of the positive effect of head motions upon the adaption process. No significant differences were found in comparison of rotational data with pre-test baseline performances. During the seven-day test period, the only statistically significant finding was among blocks of test days (B) which showed improvement of performance throughout the test (tables 122 and 123).

Ataxia. - The ataxia test battery provided three experimental combinations, each using a portion of the battery. Experiment No. 1 evaluated performance on the first and second WOFEC's, No. 2 the SR, and No. 3 the SOLEC-R and the SOLEC-L. The completed factorial design for each of these experiments during the one-day tests had four subjects (S), three rotation rates (V), four orders of administration (0), and, for tests 1 and 3, two tests. During the seven-day rotational period, the ataxia test battery provided the basis for three experiments, as before, but without the factor of rotational rates. During the one-day exposures, the following results were obtained.

WOFEC (tables 124 and 125): The analyses of results revealed that performance on WOFEC II was superior to WOFEC-1. An interaction of order and treatment occurred because this result was particularly significant for the second, third, and fourth orders of performance. This supports the conclusion that any movement dissipates the effect of adaptation to rotation and consequently assists in readaptation to the non-rotating environment.

SR (tables 126 and 127): Results of this evaluation indicated that performance improved by order of performance, that is time from cessation of rotation, but did not reach pre-rotation performance values within the first 25 minutes.

SOLEC (tables 128 and 129): No significant results were obtained for this measurement during the one-day tests except for some unexplainable interactions.

Three-day tests. - The results of the three-day tests are presented in tables 130 through 137. The analysis of each evaluation parameter revealed the following.

WOFEC (table 130 and 131): The analysis of the WOFEC results revealed that the initial trial, on day 1, was inferior to those of the next two days of rotation, indicating some adaptation after the first day. After rotation was ceased, performances immediately and two hours later were inferior to those during the last two days of rotation.

SR (tables 133 and 134): No significant findings were indicated by the analyses of variance for this measurement.

SOLEC (tables 135 through 137): Results of the analysis of variance revealed that, in the comparison of rotational with immediate post-test performance, only the SOLEC measurement obtained two hours after cessation of rotation was significantly inferior to performance on other trials, except for the post-rotation + 2-hour evaluation (table 137). Also SOLEC performance on the left leg was superior to the right leg. Possibly this reflects the fact that the test on the right leg was always performed first. Future tests will be varied in order to reduce order effects.

Postural equilibrium tests. - Measurements of postural equilibrium obtained during the seven-day rotational program were as follows:

WOFEC (tables 138 through 140): The analyses of results of test days (B), while not overwhelmingly significant when analysed for comparisons, tend to follow the expected pattern. That is to say that the last day of eyes-open performance during rotation was generally the best performance. Next in order of best performance was the last test obtained with eyes closed while the subject was rotating. After rotation ceased, performance was severely degraded and had not returned to baseline performance levels two hours after rotation ceased.

SR and SOLEC (tables 141 through 145): The analyses of results of these tests were somewhat more indicative statistically. Initial eyes-open performance was consistently better than eyes-closed performance. However, the eyes-closed performance gradually improved (not statistically significant). Post-test performance was degraded somewhat, with the two-hour performance significantly better than the worst eyes-closed measures obtained during rotation. The SR data were similar in all respects to the SOLEC values except for a low statistical probability of true differences between the performances measured on different test days.

Tangential locomotion and cargo handling. - Evaluations were conducted of test subjects walking and handling cargo while suspended in a sling system. The sling was designed to reduce the influence of the earth gravity vector. During the one-day tests, the enclosure was moved from one radius to another, being located at 70, 60, 40, and 20 feet along the beam of the RTF at each rotational rate of 3, 4, and 5 rpm. The walking surface was 15 feet long and was cantilevered from the trailing edge of the beam, providing approximately one-half of a space station deck. This configuration results in a continuously variable-g force as the test subject walks along the surface. Walking and cargo transfer were conducted in the direction of rotation (pro-spin) and out of the direction of rotation (anti-spin). It was necessary to back up to a starting position each time, with the assistance of a team mate. On the leading edge end of the room was installed an eight-chambered cabinet containing cubic-foot packages that weighed approximately five pounds each. For the cargo-handling task, the packages were removed, rotated 90 degrees in one plane and 180 degrees in the second plane and replaced at a different level in the receptacle. The objective measurements were rate or time for a complete cycle of the four packages. The walking, cargo transfer, and cargo handling were measured the same way in the three- and seven-day tests except that the room was located at the 40-foot radius and the rotational rate was limited to 4 rpm.

During the one-day tests, analyses of resultant data revealed that walking performance was significantly slower at the 20-foot radius than the other radii. Further, the performance at 3 rpm was significantly slower than that obtained at the other rotational rates (tables 146 through 149). Analyses of photographic film revealed that the reduced gravity, whether from rotational rate or radius, resulted in a shortening of the stride. At the 70-foot radius at 5 rpm, producing approximately 0.6 g's, the stride was approximately 26 inches. At this same radius, at 3 rpm, with a gravity field of approximately 0.2 g's, the stride was approximately 15 inches. These stride lengths were duplicated approximately at the 40- and 60-foot levels but not at the 20-foot level. The degraded performance at the 20-foot level is directly attributable to the interaction of low g, Coriolis forces, and relative angles of the floor producing a variable-g force from the back of the room to the center line located over the beam of the RTF. On the basis of observations and subjective comments, it was tentatively concluded that flat floors were highly acceptable at the 60- and 70-foot radii and at 40 feet, with some loss of control during locomotion at the 3 and 4 rpm rates (0.12 and 0.21 g's). It was concluded that flat floors were unsatisfactory at the 20-foot radius, even though locomotion was accomplished at the 4 and 5 rpm rates (0.11 and 0.17 g's) with great difficulty.

Analyses of cargo transfer evaluations (tables 150 through 153) demonstrated that the performance at 3 rpm was significantly slower than either 4 or 5 rpm, and the performance at the 20-foot radius was significantly slower than at the other radii. Cargo transfer was significantly better in the pro-spin orientation. These same results were obtained with respect to cargo pick-up (tables 154 through 156). Cargo handling showed only one significant factor, that being that performance was slower at the 3 rpm rates than at either 4 or 5 rpm (tables 157 through 159).

Radial locomotion - ladder and elevator. - All test subjects were timed during radial transfer during the test series. During the one-day tests, locomotion was evaluated on the ladder in the pro-spin and anti-spin directions while test subjects ascended and descended the ladder at all three rotational rates. The analysis of variance of the results obtained during ladder climbing did not provide any meaningful results (tables 160 and 161). Several interactions were statistically significant, but conclusions were not apparent. However, these measures were basically secondary to the subjective comments, excessive effort. At 5 rpm, forces were comfortable from about 10 feet to the 30-foot radius (0.08 to 0.25 g's), but felt excessive at radii greater than 30 feet (0.25 to 0.55 g's).

The rate of ladder traversal at all rotational rates and orientations averaged approximately 1.34 feet per second. It was found that ascent was slightly faster than descent as was the pro-spin orientation in comparison to the anti-spin direction. These values do not lend themselves to careful analyses because of test subject experimentation.

The test subjects observed that, although sling problems associated with pulley hangups and learning techniques tended to mask some of the evaluations, it was evident that ladder traversal for radial movement could be easily accomplished. A preference for direction of body position during ascent and descent was initially established as facing pro-spin for ascent and anti-spin for descent regardless of whether the rotational velocity was 3, 4, or 5 rpm. As the tests progressed and sling adjustment became less of a hinderance, it was more difficult to qualify a preference for direction of body positioning and it became evident that a positive, moderate pace could be used for satisfactory progress in ascent and descent regardless of body orientation. Although it is considered that a ladder could be used by crew personnel for radial traverses in a rotating environment in space, it should be a secondary or backup method. Some other motive method (electrically or hand-driven elevator) should be provided for crew convenience and ease of transport. Although initial preferences were expressed, with respect to direction of ascent or descent, these were masked upon continued testing. At the 5 rpm rotational rate, a general preference for facing pro-spin was expressed for both ascent and descent. Ascent was reported to provide a more secure feeling than descent.

Radial transfer using the elevator (cart) resulted in positive statements relative to the use of this mode of transfer between levels in a space station/base complex. The subjects reported a significant impression of curved rather than linear transfer at the 4 and 5 rpm rates and elevator rates of 4 or 6 feet per second. The intensity of this illusion appeared to be a function of both the rotational and linear velocities coupled with subject orientation; i.e., the higher the velocities the more intense the illusion, with maximum intensity being experienced in the face-down position, followed closely by the face-up position. There appeared to be a significant reduction in intensity in both the pro- and anti-spin orientations, with no significant difference being noted between the two. The subjective impression of the curvilinear phenomena was believed to be principally a result of the initial acceleration of the elevator, with the continuance of the illusion being dependent upon the Coriolis forces resulting from the linear velocity. One test subject reported that the body motions induced by Coriolis and other rotational forces were mild and not at which are summarized briefly. The test subjects observed that use of a ladder as a means of radial transfer could induce the following operational and design problems:

1. Both ascent and descent was accomplished, subjectively, with the expenditure of less energy while facing in the pro-spin than in the anti-spin direction. A personal preference was, however, developed for the anti-spin direction as a result of the impression of a more positive footing.

2. The use of a ladder, as a means of radial transfer, might require rest or safety platforms in much the same positions (configuration-wise) as in a one-g environment. Physical spacing of these platforms would be of a progressively decreasing nature and a function of the rotational rate and the distance from the radius of rotation.

3. Difficulty in transfer along the ladder appeared primarily attributable to the constantly changing magnitude of the artificial-gravity force vector. This effect may be reduced significantly by progressive spacing of the ladder rungs, but could probably not be completely eliminated by ladder design.

4. A completely reliable assessment of operational problems associated with the use of a ladder as a means of radial transfer was complicated by inadequacies in the harness-trolley operation. In all cases, the difference in personal preference between the pro- and anti-spin orientations was minimal and conceivably could have been attributable to the experimental apparatus.

5. At 3 rpm, the artificial-g forces are not sufficient to warrant the use of feet on the ladder rungs from a radius of 10 feet (0.03 g's) to approximately 30 feet (0.09 g's). The use of the ladder, as a ladder, required exertion of additional energy by the subject to accomplish foot placement in these low force fields. Therefore, the use of rungs up to this radius may be superflous, except for maintaining body position. From the 30-foot radius to the 65-foot radius (0.19 g's) the forces were sufficient to warrant use of the rungs without the expenditure of additional effort for foot placement. Transfer along the length of the ladder at 4 rpm (0.05 g's to 0.34 g's), was, subjectively, the most acceptable of the three rotational rates. The transition, relative to force changes, at the 25- to 30-foot radius (0.13 to 0.16 g's) was still noticeable, but the forces were not uncomfortable at radii greater than 30 feet. At this rotational rate, the forces at radii less than 30 feet were minimal, but foot placement could still be accomplished without

all uncomfortable during traverses. Other sensations were equally mild, and no problems associated with radial movement in a rotating environment were noted. A definite preference for this type of radial traverse over the ladder was developed. Only the hydraulically powered elevator cart was evaluated during this test, but other methods of powering the elevator such as hand-operated pulleys or cranks would probably provide sufficient motive power in the rotating environment to provide for radial traverse of both personnel and cargo. It was observed that at linear rates of greater than 6 feet per second that handholds or other restraints may be required to counteract the lateral forces generated by the linear motion.

The walking evaluations obtained during the three-day tests (tables 162 and 163) and the seven-day tests (tables 164 and 165) revealed again that walking performance improved between test days and that performance in the pro-spin direction is superior to that in the anti-spin direction, while the floor is located at a radius of 40 feet. The test subjects observed that the learning curve for walking at the 0.22-g level continued throughout the longer-duration tests. It was the concensus that curved floors would not significantly improve performance at radii of 40 feet or greater. At these low-g levels, the cargo mass could be used as additional weight to increase both traction and stability.

Cargo transfer during the three- and seven-day tests (tables 166 through 169, respectively) revealed upon analyses that the performance in the pro-spin direction was superior to that obtained in the anti-spin orientation.

Cargo pick-up (tables 170 through 173) yielded significant results that demonstrated the superiority of performance while the test subjects were facing the pro-spin direction.

No significant findings were forthcoming from the three- and seven-day cargo handling tasks (tables 174 through 177).

The force-pull task was inserted during the three-day test and continued during the seven-day rotational period. These data, presented in tables 178 through 181, indicate that the forward pull was more effective than the overhead pull and greater while facing the pro-spin than the anti-spin orientation. This interpretation, while considered valid, cannot lead to more conclusions because of the trial-and-error nature of the task as employed in this study.

Radial locomotion, using a rope suspended between the ladders, was deemed by the subjects to be too difficult at the 4 rpm rate. Also it was felt to be an unsafe method of locomotion. The sensation was very much akin to the feeling of climbing a rope in the normal environment.

TABLE 5. - ENGINEERING VOLUNTEERS FOR TEST SUBJECTS

SUBJECT	AGE (Yrs)	HEIGHT (Inches)	WEIGHT (Lbs.)	WORK CAPACITY (Minutes) *
A	34	70	165	18
B	40	72	215	12(16)
C	47	68	189	13(15)
D	48	70	160	16
E	47	69	195	11(15)
F	31	69	165	9
G	38	68	153	10(15)
H	37	71	175	18

*Treadmill Evaluation
**Score following 5 weeks graded physical activity program
---Not done

TABLE 6. - TEST SUBJECT CALIBRATION

Subj	Age	Caloric Tests				Perception OCI. ANG. ACC.		Counter-Rolling Index	Posture Equilibr. Tests	Provocative Tests					
		NYS. Threshold		Mod. Hallpike						Dial Test SRR			CSSI		
		Response (°C)		Preponderance		Deg. /Sec^2									
		R	L	Direction	Labyrint	CW	CCW			RPM	No. H. M.	Susceptibility	RPM	No. H. M.	Susceptibility
A	34	Normal 36.3	Normal 36.2	Normal 3% L>R	Normal 9% R>L	Normal 0.024	Normal 0.19	Normal 351	Border-line to superior	15	100	Low average	125	150	Far below average
B	40	Normal 36.2	Normal <36.2 >36.4	Normal 3% L>R	Normal 14% R>L	Normal 0.024	Normal 0.024	Normal 348	Low-old ankle injury	15	25	Low average	Not done		
C	47	Normal 35.8	Normal 35.8	Normal 0% R = L	Normal 11% R>L	Normal 0.03	Normal 0.03	Normal 384	Above average	5	50	Above average	15	20	(4.1)* Above average
D	49	Normal 36.4	Normal 36.3	Normal 5% R>L	Normal 5% L>R	Normal 0.076	Normal 0.03	Techni-cal error	Above average	10	100	Average	Not done		
E	47	Normal 35.9	Normal 35.9	Normal 4% R>L	Normal 12% R>L	Normal 0.19	Normal 0.38	Normal 178	Border-** line to superior	15	15	Low average	20	70	(23.1)* Below average
F	32	Normal 36.0	Normal 35.6	Normal 6% L>R	Normal 3% R>L	Normal 0.30	Normal 0.06	Normal 214	Above average	20	15	Far below average	15	75	(15.4)* Below average
G	39	Normal 36.6	Normal 36.4	Normal 17% L>R	Normal 23% L>R	Normal 0.19	Normal 0.19	Normal 176	Above average	20	100	Far below average	15	150	Far below average
H	37	Normal 36.2	30.0	Left vestibular apparatus nonfunctional		Normal 0.12	Normal 0.15	Normal 354	Some below average	15	3	Average	10	45	High (4.7)* average

*Susceptibility index
**Old pelvic fracture

TABLE 7. - PHYSIOLOGICAL RESPONSES - ONE-DAY TESTS

MEASUREMENT*	SUBJECT			
	A	B	C	D
Pre-heart rate (BPM)	75	75	69	64
Post-heart rate	79	85	77	74
Pre-blood pressure (mm Hg)	116/69	122/74	133/77	123/69
Post-blood pressure	117/76	121/76	135/77	120/68
Pre-hematocrit (%)	51	59	52	52
Post-hematocrit	53	52	52	53
Pre-urine specific gravity	1.019	1.016	1.015	1.015
Post-urine specific gravity	1.024	1.024	1.018	1.017
Pre-urine pH	5.75	5.50	5.99	5.86
Pre-urine pH	5.89	5.90	6.91	7.06
Body weight change (lb)	-0.44	-1.56	-2.19	-0.56

*Mean values

TABLE 8. - MEAN HEART RATE* DURING PASSIVE RADIAL TRANSFER

ORIENTATION	ROTATIONAL RATE (RPM)							
	3		4		5		ALL	
	ASCENT	DESCENT	ASCENT	DESCENT	ASCENT	DESCENT	ASCENT	DESCENT
Pro-spin	63	63	65	62	62	63	63	63
Axial	61	67	59	67	58	62	59	65
Anti-spin	65	67	61	66	61	66	62	66
All	63	66	62	65	60	64	61	65

*Beats/minute

TABLE 9. - MEAN HEART RATES* DURING STATION CHANGES AND TESTING - ONE-DAY TESTS

CONDITION	ROTATIONAL RATE (RPM)			
	3	4	5	ALL
Control (in crew module)	83.7*	88.3	95.6	89
Crew module to all stations	102.8	107.0	109.1	106
All stations to crew module	101.8	107.4	96.9	102
Hub to all stations	92.0	98.8	88.6	93
All stations to hub	104.4	105.4	100.3	103
30-ft-radius to all stations	94.9	104.4	89.6	96
All stations to 30-ft radius	91.6	107.9	96.1	99
78-ft radius to all stations	104.1	112.2	100.5	106
All stations to 78-ft radius	96.2	102.9	100.9	100
DRT hub	76.6	80.3	80.8	79
DRT 30-ft radius	76.6	77.7	78.2	78
DRT 78-ft radius	72.7	79.7	78.1	77
Ataxia (RTF stopped)	106.0	108.0	105.0	

*Beats/minute

TABLE 10. - PHYSIOLOGICAL DATA - THREE-DAY TEST

MEASUREMENT*	TEST SUBJECT			
	A	B	C	D
Pre-heart rate (BPM)	75	75	85	68
Test heart rate	80	81	93	70
Pre-blood pressure (mm Hg)	116/69	122/74	120/98	124/82
Test blood pressure	121/84	122/90	116/79	120/83
Body weight change (lb)	0	1	2.2	0
Horizontal phoria**				
Day 1	+2	+1	+3	+6
Day 2	-2	+1	+2	+6
Day 3	+1	+1	+2	+3

*Mean values
**+Exophoria
0 Orthophoria
- Esophoria

TABLE 11. - BICYCLE ERGOMETRY - SEVEN-DAY TEST

MEASUREMENT*	PRE-TEST	POST-TEST
O_2 Consumption (L/min)	2.21	2.34
CO_2 tension (mm Hg)	26.0	28.0
Respiratory quotient	0.90	0.93
End heart rate (beats/min)	151.0	157.0

*Mean values at 10th minute

TABLE 12. - PULMONARY FUNCTION - SEVEN-DAY TEST

MEASUREMENT*	PRE-TEST	POST-TEST
Vital capacity (ml)	4667	4444
1-second forced VC (%)	74	80
1-second forced expired volume (ml)	3393	3352
Max ventilatory volume (L/min)	140	146

*Mean values

TABLE 13. - HORIZONTAL PHORIA DURING ROTATION - SEVEN-DAY TEST

DAY	SUBJECTS			
	A	B	D	G
1	+1	+3	+2	+6
2	+1	+1	+1	+6
3	+4	-1	-7	-1
4	-3	0	-3	+4
5	-1	-3	-2	+1
6	-1	0	-5	+1
7	-3	0	-2	+7

\+ Exophoria
0 Orthophoria
\- Esophoria

TABLE 14. - BLOOD CHEMISTRY - SEVEN-DAY TEST

MEASUREMENT*	PRE-TEST	POST-TEST
RBC (No./ml x 10^3)	5,468	5,470
Hemoglobin (mg/100 ml)	15.8	15.6
Hematocrit (%)	47.0	46.9
WBC (No./ml)	7,525	7,125
Sed rate (mm/Hr)	12	12
Cholesterol (mg/100 ml)	234	244
Calcium (mg/100 ml)	9.7	10.5
Uric acid (mg/100 ml)	5.0	5.5
Urea nitrogen (mg/100 ml)	27.0	11.0
Glucose (mg/100 ml)	90.0	86.0
Lactic dehydrogenase (units)	128.0	141.0
SGOT (units)	11.0	27.0
Bilirubin (mg/100 ml)	0.59	0.60
Albumen (gm/100 ml)	4.56	5.00
Globulin (gm/100 ml)	2.42	2.62

*Mean values

TABLE 15. - LCC BASELINE DATA

SUBJECT	1st WEEK	END OF LAB TR	PRE 8 HR	POST 8 HR	PRE 3-DAY	POST 3-DAY	PRE 7-DAY
A	112.5*	82.86	79.55	72.0	73.0	79.0	73.0
B	118.95	82.85	82.0	79.0	76.0	76.0	71.0
C	96.35	81.15	80.52	82.5	----	----	----
D	120.45	113.25	109.0	97.5	----	----	98.0
F	105.26	----	----	----	101.0	100.0	----
G	99.16	----	----	----	80.0	84.0	80.0

* MEAN TIME IN SECONDS
---- NOT MEASURED

TABLE 16. - DRT BASELINE DATA

A. Standard Mode

SUBJECT	1st WEEK	END OF LAB TR	PRE 8 HR	POST 8 HR		PRE 3-DAY	POST 3-DAY	PRE 7-DAY
				HUB	30'			
A	25.33*	25.92	26.75	28.0	27.45	27.11	----	27.77
B	25.08	25.17	26.33	27.42	26.8	27.33	----	31.55
C	27.17	26.42	27.08	26.58	27.5	----	----	----
D	26.08	26.33	26.42	26.69	26.85	27.4	----	26.77
F	26.75	----	----	----	----	28.16	31.08	----
G	25.83	----	----	----	----	25.16	25.8	26.0

* Mean Total Responses

SUBJECT	1st WEEK	END OF LAB TR	PRE 8 HR	POST 8HR		PRE 3-DAY	POST 3-DAY	PRE 7-DAY
				HUB	30'			
A	25.25**	17.75	16.0	14.92	15.2	13.55	----	13.6
B	24.83	18.33	17.75	17.0	16.5	14.5	----	13.44
C	37.16	26.0	23.25	19.17	20.3	----	----	----
D	30.67	29.16	19.33	16.15	18.35	16.0	----	15.77
F	23.33	----	----	----	----	18.83	19.0	----
G	29.33	----	----	----	----	20.25	18.3	17.7

** Mean Time in Seconds

TABLE 17. - DRT BASELINE DATA

	B. ALTERNATING DISPLAYS			C. CONTINUOUS RUN			D. CONTINUOUS CODE CHANGE		
SUBJECT	PRE 3-DAY	POST 3-DAY	PRE 7-DAY	PRE 3-DAY	POST 3-DAY	PRE 7-DAY	PRE 3-DAY	POST 3-DAY	PRE 7-DAY
A	27.75*	----	----	26.37*	----	26.36	26.7*	----	29.1
B	26.5	----	----	26.57	----	26.68	25.9	----	29.
D	26.75	----	----	26.94	----	29.73	29.8	----	27.55
F	28.5	----	----	28.08	----	29.73	29.4	32.75	----
G	26.	----	----	26.03	26.57	25.78	27.1	27.2	28.1

*Mean Total Responses

SUBJECT	PRE 3-DAY	POST 3-DAY	PRE 7-DAY	PRE 3-DAY	POST 3-DAY	PRE 7-DAY	PRE 3-DAY	POST 3-DAY	PRE 7-DAY
A	29.5**	----	----	15.55**	----	13.61	25.3**	----	21.2
B	28.13	----	----	14.27	----	15.66	24.36	----	25.1
D	27.75	----	----	17.19	----	15.58	25.8	----	27.3
F	30.75	----	----	20.58	----	----	27.9	27.92	----
G	29.25	----	----	22.33	19.14	18.57	24.0	25.4	24.3

**Mean Time in Seconds

TABLE 18. - STANDARD STROMBERG BASELINE DATA

SUBJECT	1st WEEK	PRE 8-HR	POST 8-HR	PRE 3-DAY	POST 3-DAY	PRE 7-DAY
A	57.0*	44.83	46.63	44.0	43.0	43.0
B	60.17	48.33	49.83	46.33	----	43.5
C	56.17	41.17	48.17	----	----	----
D	67.0	51.33	50.83	49.0	----	45.6
F	56.43	----	----	48.0	----	----
G	63.0	----	----	52.17	50.0	49.8

* Mean Time in Seconds

TABLE 19. - MODIFIED STROMBERG BASELINE DATA

SUBJECT	1st WEEK	PRE 8-HR	POST 8-HR
A	58.33*	54.66	48.67
B	67.33	58.66	51.63
C	64.67	63.0	59.2
D	66.33	60.66	54.46

*Mean Time in Seconds

TABLE 20. - PURSUIT ROTOR BASELINE DATA

SUBJECT	PRE 3-DAY	POST 3-DAY	PRE 7-DAY
A	40.1*	54.91	45.55
B	39.63	53.0	53.75
D	----	----	41.85
F	40.99	51.73	----
G	39.26	51.58	54.16

*Mean Time in Seconds

TABLE 21. - MENTAL ARITHMETIC BASELINE DATA

SUBJECT	PRE 3-DAY	PRE 7-DAY
A	9*	9
B	10	10
D	9	9
F	9	9
G	10	10

*Modal Correct Answers

TABLE 22. - MEMORY DRUM BASELINE DATA

A. First Four Trials

SUBJECT	PRE 3-DAY	PRE 7-DAY
A	13.0*	15.75
B	18.66	20.5
D	13.0	11.66
F	14.33	21.0
G	21.0	20.0

*Mean Score

B. All Correct Trials

SUBJECT	PRE 3-DAY	PRE 7-DAY
A	12.5*	8.0
B	8.33	5.5
D	12.33	12.0
F	7.66	6.0
G	4.0	4.66

*Mean Score

TABLE 23. - ATAXIA BASELINE DATA

SUBJECT		1st WEEK	PRE 8-HR	POST** 8-HR	POST** 3-DAY	PRE 7-DAY
A	WOFEC-I	15**	17	22	30	25
	SR	87	180	180	180	180
	SOLEC-R	50	90	75	90	90
	SOLEC-L	32	90	90	90	90
	WOFEC-II	8	27	17	30	16
B	WOFEC-I	7	27	24	18	19
	SR	180	180	180	180	180
	SOLEC-R	21	31	27	17	12
	SOLEC-L	90	90	90	90	90
	WOFEC-II	8	28	20	19	17
C	WOFEC-I	30	30	22		
	SR	180	180	180		
	SOLEC-R	83	90	90		
	SOLEC-L	90	90	90		
	WOFEC-II	30	30	8		
D	WOFEC-I	28	30	30	28	23
	SR	180	180	180	180	180
	SOLEC-R	90	90	89	90	90
	SOLEC-L	90	90	90	90	90
	WOFEC-II	25	30	30	30	25
F	WOFEC-I	22			30	
	SR	180			180	
	SOLEC-R	90			90	
	SOLEC-L	90			89	
	WOFEC-II	28			23	
G	WOFEC-I	25			23	25
	SR	180			180	180
	SOLEC-R	90			90	90
	SOLEC-L	90			90	90
	WOFEC-II	26			30	30

* Score
** Several Days Post-Rotation

TABLE 24. - LCC - NEWMAN-KUELS ANALYSIS OF "R" FACTORS - ONE-DAY TESTS

	POST	R_4	R_3	PRE	R_2	R_1
POST	---	163.*	191.*	361.26**	424.**	607.**
R_4		--	28.	198.26 *	261.*	444.**
R_3			--	170.26*	233.*	416.*
PRE				--	62.74	254.74*
R_2					--	183.*
R_1						--

** Significant at .01 Level
* Significant at .05 Level

TABLE 25. - LCC PERFORMANCE TIME ANALYSIS OF VARIANCE - ONE-DAY TESTS

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBABILITY
S	76428.18750	3	25476.06250		
O	16.43054	2	8.21527	.164	---
SO	300.90259	6	50.15042		
A	134.76389	2	67.38194	2.736	<.2
SA	147.73610	6	24.62268		
OA	152.11110	4	38.02777	1.006	---
SOA	453.55542	12	37.79628		
R	3658.85400	3	1219.61792	19.574	<.001
SR	560.78467	9	62.30940		
OR	128.62500	6	21.43750	.329	---
SOR	1171.15259	18	65.06403		
AR	2584.12500	6	430.68750	5.215	<.005
SAR	1486.48608	18	82.58255		
OAR	309.33325	12	25.77777	.485	---
SOAR	1913.87646	36	53.16322		
TOTAL	89446.50000	143			

CODE-FACTORS
- S- SUBJECTS
- O- ORIENTATIONS
- A- RPM
- R- REPLICATIONS

LEVELS
- 1 = A, 2 = B, 3= C, 4 = D
- 1 = Pro-Spin, 2 = Axial, 3= Anti-Spin
- 1 = 3 RPM, 2 = 4 RPM, 3 = 5 RPM
- 1 = 1st Trial, 2 = 2nd Trial, 3 = 3rd Trial, 4 = 4th Trial

TABLE 26. - LCC MEAN PERFORMANCE TIMES - ONE-DAY TESTS

A_1* 173.75**	A_2 175.79	A_3 175.81	
O_1 175.48	O_2 174.67	O_3 175.21	
R_1 182.36	R_2 177.28	R_3 170.81	R_4 170.03
S_1 153.83	S_2 166.89	S_3 165.72	S_4 214.03

* See Table 25 for Code

** Mean Time in Seconds for 100 Problems

TABLE 27. - LCC PERFORMANCE TIME ANALYSIS OF VARIANCE - THREE-DAY TEST

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBAB-ILITY
S	9223.50000	3	3074.50000		
A	1.75000	2	0.87500	0.013	----
SA	405.25000	6	67.54166		
R	42.66666	1	42.66666	1.386	----
SR	92.33333	3	30.77777		
AR	37.58333	2	43.79166	4.41	<.1
SAR	55.41666	6	9.23611		
TOTAL	9908.49219	23			

CODE-FACTORS	LEVELS
S- SUBJECTS	1=A, 2=D, 3=F, 4=G
A- HEAD MOVEMENTS	1=0, 2=5, 3-10
R- REPLICATIONS	1=1st, 2=2nd

TABLE 28. - LCC MEAN PERFORMANCE TIMES - THREE-DAY TEST

A_1* 165.63**	A_2 166.13	A_3 165.5	
R_1 167.08	R_2 164.42		
S_1 149	S_2 150	S_3 197.5	S_4 166.5
GRAND MEAN 165.75000			

* See Table 27 for Code
** Mean Time in Seconds for 100 Problems

TABLE 29. - LCC PERFORMANCE TIME ANALYSIS OF VARIANCE - SEVEN-DAY TEST

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBABILITY
S	27367.48438	3	9122.49219		
B	21.36110	2	10.68055	0.119	---
SB	539.30542	6	89.88423		
H	25.86110	2	12.93055	0.231	---
SH	336.13867	6	56.02310		
BH	165.55554	4	41.38889	1.459	---
SBH	340.44434	12	28.37036		
R	55.12500	1	55.12500	0.517	---
SR	319.70825	3	106.56941		
BR	97.58333	2	48.79166	1.082	---
SBR	270.41650	6	45.06941		
HR	85.58333	2	42.79166	1.050	---
SHR	244.41666	6	40.73610		
BHR	92.83333	4	23.20833	0.680	---
SBHR	409.83325	12	34.15277		
TOTAL	30371.62891	71			

CODE-FACTORS

S- SUBJECTS	1=A, 2-B, 3=D, 4-G
B- BLOCKS OF DAYS	1=Days 1+2, 2=Days 3-5, 3=Day 6 +7
H- HEAD MOVEMENTS	1=0, 2=5, 3=10
R- REPLICATIONS	1=1st, 2=2nd

TABLE 30. - LCC MEAN PERFORMANCE TIMES - SEVEN-DAY TEST

B_1* 158.29	B_2 157.67	B_3 159.0	
H_1 157.92	H_2 157.88	H_3 159.17	
R_1 159.19	R_2 157.44		
S_1 144.44	S_2 139.06	S_3 189.17	S_4 160.61
GRAND MEAN 158.31944			

* See Table 29 for Codes
** Mean Time in Seconds for 100 Problems

TABLE 31. - DRT RESPONSES ANALYSIS OF VARIANCE - ONE-DAY TESTS (STD 30- AND 78-FT STATIONS)

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBA-BILITY
S	22.72748	3	7.57583		
T	0.52734	1	0.52734	2.843	< .2
ST	0.55637	3	0.18546		
A	0.60702	1	0.60702	1.518	----
SA	1.19952	3	0.39984		
TA	0.02930	1	0.02930	.192	----
STA	0.45675	3	0.15225		
V	1.01846	2	0.50923	1.288	----
SV	2.37060	6	0.39510		
TV	2.91639	2	1.45819	3.836	< .1
STV	2.28062	6	0.38010		
AV	2.65396	2	1.32698	3.758	< .1
SAV	2.11845	6	0.35308		
TAV	0.84745	2	0.42373	1.667	----
STAV	1.52446	6	0.25408		
R	0.05484	1	0.05484	.074	----
SR	2.21534	3	0.73845		
TR	0.00230	1	0.00230	.004	----
STR	1.56368	3	0.52123		
AR	0.03692	1	0.03692	.156	----
SAR	0.70781	3	0.23594		
TAR	0.88494	1	0.88494	5.502	< .2
STAR	0.48245	3	0.16082		
VR	0.88865	2	0.44433	.783	----
SVR	3.40434	6	0.56739		
TVR	3.63487	2	1.81743	6.004	< .05
STVR	1.81623	6	0.30270		
AVR	4.82679	2	2.41340	6.915	< .05
SAVR	2.09382	6	0.34897		
TAVR	0.54813	2	0.27407	.392	----
STAVR	4.18872	6	0.69812		
O	1.14808	4	0.28702	.967	----
SO	3.55975	12	0.29665		
TO	0.52867	4	0.13217	.563	----
STO	2.81493	12	0.23459		

TABLE 31. - DRT RESPONSES ANALYSIS OF VARIANCE - ONE-DAY TESTS
(STD 30- AND 78-FT STATIONS) - continued

AO	0.79996	4	0.19999	.586	----
SAO	4.08921	12	0.34077		
TAO	2.65588	4	0.66397	2.722	<.1
STAO	2.92617	12	0.24385		
VO	1.74234	8	0.21779	.565	----
SVO	9.23653	24	0.38486		
TVO	3.42543	8	0.42818	1.297	----
STVO	7.92219	24	0.33009		
AVO	1.93223	8	0.24153	.775	----
SAVO	7.47533	24	0.31147		
TAVO	3.78450	8	0.47306	.866	----
STAVO	13.10062	24	0.54587		
RO	2.91947	4	0.72987	1.679	----
SRO	5.21509	12	0.43459		
TRO	1.07759	4	0.26940	.785	----
STRO	4.11680	12	0.34307		
ARO	3.13227	4	0.78307	3.869	<.05
SARO	2.42848	12	0.20237		
TARO	0.09850	4	0.02462	.086	----
STARO	3.43199	12	0.28600		
VRO	3.28906	8	0.41113	1.100	----
SVRO	8.96646	24	0.37360		
TVRO	5.79992	8	0.72499	1.345	----
STVRO	12.92904	24	0.53871		
AVRO	1.03531	8	0.12941	.285	----
SAVRO	10.88538	24	0.45356		
TAVRO	5.41623	8	0.67703	1.619	<.2
STAVRO	10.03550	24	0.41815		
TOTAL	217.10250	479			

CODE-FACTORS	LEVELS
S - SUBJECTS	1=A, 2=B, 3-C, 4-D
T - TIME OF DAY	1= AM, 2= PM
A - STATIONS	1= 30', 2= 78'
V - RPM	1= 3, 2= 4, 3= 5
R - REPLICATIONS	1= 1st, 2= 2nd
O - ORIENTATIONS	1= Pro-Spin, 2= 45° Pro-Spin, 3= Axial, 4= 45° Anti-Spin, 5= Anti-Spin

TABLE 32. - DRT RESPONSES - ONE-DAY TESTS (STD 30- AND 78-FT STATIONS)

A_1* ** 26.29	A_2 26.21			
O_1 26.23	O_2 26.23	O_3 26.32	O_4 26.17	O_5 26.29
R_1 26.24	R_2 26.26			
S_1 26.53	S_2 26.10	S_3 26.40	S_4 25.99	
T_1 26.29	T_2 26.22			
V_1 26.23	V_2 26.20	V_3 26.32		
GRAND MEAN 26.25357				

* See Table 31 for Code
** Mean Responses per 25 Lights

TABLE 33. - DRT RESPONSES - NEWMAN-KUELS ANALYSIS OF "A" FACTOR (STD 30- AND 78-FT STATIONS) - ONE-DAY TESTS

A_2	A_1	PRE	POST-HUB	POST-30'
A_2 --	20.05	104.47**	231.07**	231.67**
A_1	---	84.42*	211.02**	211.62**
PRE		---	126.6**	127.2**
POST-HUB			---	.6
POST-30'				---

** Significant at the .01 Level
* Significant at the .05 Level

TABLE 34. - DRT PERFORMANCE TIME ANALYSIS OF VARIANCE (STD 30- AND 78-FT STATIONS) - ONE-DAY TESTS

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBA-BILITY
S	1809.80298	3	603.26758		
T	2.76185	1	2.76185	4.448	< .2
ST	1.86241	3	0.62080		
A	4.52600	1	4.52600	6.658	< .1
SA	2.03917	3	0.67972		
TA	0.01419	1	0.01419	.012	--
STA	3.52538	3	1.17513		
V	9.99995	2	4.99998	2.115	--
SV	14.18139	6	2.36356		
TV	239.04628	2	119.52313	45.631	< .001
STV	15.71596	6	2.61933		
AV	1.34743	2	0.67372	.482	--
SAV	8.38226	6	1.39704		
TAV	2.84606	2	1.42303	1.474	--
STAV	5.79131	6	0.96522		
R	90.34967	1	90.34967	18.397	< .025
SR	14.73262	3	4.91087		
TR	1.07826	1	1.07826	2.015	--
STR	1.60503	3	0.53501		
AR	0.17903	1	0.17903	.062	--
SAR	8.61504	3	2.87168		
TAR	0.92312	1	0.92312	.281	--
STAR	9.74387	3	3.24796		
VR	20.12607	2	10.06303	4.060	< .1
SVR	14.86820	6	2.47803		
TVR	4.43252	2	2.21626	1.795	--
STVR	7.40431	6	1.23405		
AVR	8.38497	2	4.19248	1.180	--
SAVR	21.30276	6	3.55046		
TAVR	2.05183	2	1.02592	1.148	--
STAVR	5.36103	6	0.89350		
D	9.49616	4	2.37404	1.788	< .2
SD	15.93240	12	1.32770		
TD	2.58650	4	0.64662	.921	--
STD	8.42332	12	0.70194		
AD	2.70736	4	0.67684	1.180	--

TABLE 34. - DRT PERFORMANCE TIME ANALYSIS OF VARIANCE (STD 30- AND 78-FT STATIONS) - ONE-DAY TESTS - continued

SAO	6.87934	12	0.57328		
TAO	1.02739	4	0.25685	.437	--
STAO	7.04334	12	0.58694		
VO	5.48336	8	0.68542	.534	--
SVO	30.77921	24	1.28247		
TVO	6.45374	8	0.80672	1.212	--
STVO	15.97231	24	0.66551		
AVO	9.35919	8	1.16990	1.366	--
SAVO	20.54198	24	0.85592		
TAVO	17.83886	8	2.22986	1.610	< .2
STAVO	33.23322	24	1.38472		
RO	1.09479	4	0.27370	.339	
SRO	9.66943	12	0.80579		
TRO	0.84105	4	0.21026	.156	--
STRO	16.09923	12	1.34160		
ARO	1.94699	4	0.48675	.652	--
SARO	8.95132	12	0.74594		
TARO	1.89449	4	0.47362	.695	--
STARO	8.16920	12	0.68077		
VRO	8.95423	8	1.11928	.903	--
SVRO	29.73460	24	1.23894		
TVRO	9.07716	8	1.13464	1.028	--
STVRO	26.46970	24	1.10290		
AVRO	6.22661	8	0.77833	.872	--
SAVRO	21.41811	24	0.89242		
TAVRO	18.57668	8	2.32208	1.795	< .2
STAVRO	31.04446	24	1.29352		
TOTAL	2726.91919	479			

* CODE - SEE TABLE 31.

TABLE 35. - DRT PERFORMANCE TIMES (STD 30- AND 78-FT STATIONS) - ONE-DAY TESTS

A_1* 18.86**	A_2 18.50			
O_1 18.51	O_2 18.50	O_3 18.69	O_4 18.83	O_5 18.86
R_1 19.14	R_2 18.22			
S_1 16.21	S_2 17.68	S_3 21.45	S_4 19.16	
T_1 18.52	T_2 18.73			
V_1 18.95	V_2 18.70	V_3 18.39		
GRAND MEAN 18.65604				

* See Table 31 for Code
** Mean Time in Seconds per 25 Lights

TABLE 36. - DRT PERFORMANCE TIMES - NEWMAN-KUELS ANALYSIS OF "A" FACTOR (STD 30- AND 78-FT STATIONS) **1-DAY TESTS**

	POST-HUB	POST-30'	A_2	A_1	PRE
POST-HUB	----	186.7**	406.17**	492.02**	545.5**
POST-30'		----	219.47**	305.32**	358.8**
A_2			----	85.85	139.33**
A_1				----	53.48
PRE					----

** Significant at the .01 Level
* Significant at the .05 Level

TABLE 37. - DRT PERFORMANCE TIME ANALYSIS OF VARIANCE (STD - ALL STATIONS) - ONE-DAY TESTS

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBA-BILITY
S	525.18848	3	175.06282		
A	5.17547	2	2.58774	2.253	< .2
SA	6.83903	6	1.14817		
T	9.46596	1	9.46596	21.807	< .025
ST	1.30219	3	0.43406		
AT	0.13911	2	0.06955	4.320	< .10
SAT	0.96406	6	0.16068		
V	0.91105	2	0.45552	2.509	< .20
SV	1.08908	6	0.18151		
AV	2.06425	4	0.51606	.850	--
SAV	7.28047	12	0.60671		
TV	25.83633	2	12.91817	17.118	< .005
STV	4.52787	6	0.75465		
ATV	1.26332	4	0.31583	.528	--
SATV	7.16902	12	0.59742		
R	28.37329	1	28.37329	16.675	< .05
SR	5.10450	3	1.70150		
AR	0.38189	2	0.19095	.301	--
SAR	3.79751	6	0.63292		
TR	14.52894	1	14.52894	356.353	< .001
STR	0.12230	3	0.04077		
ATR	4.25381	2	2.12691	1.506	--
SATR	8.47213	6	1.41202		
VR	14.05050	2	7.02525	19.210	< .005
SVR	2.19411	6	0.36569		
AVR	4.65489	4	1.16372	.873	--
SAVR	15.93929	12	1.33244		

TABLE 37. - DRT PERFORMANCE TIME ANALYSIS OF VARIANCE (STD - ALL STATIONS) - ONE-DAY TESTS - continued

TVR	18.47044	2	9.23522	8.702	<.025
STVR	6.36743	6	1.06124		
ATVR	3.18638	4	0.79672	1.331	--
SATVR	7.18154	12	0.59846		
TOTAL	736.39111	143			

CODE-FACTORS	LEVELS
S - SUBJECTS	1=A, 2=B, 3=C, 4=D
A - STATIONS	1=Hub, 2=30', 3=78'
T - TIME OF DAY	1=AM, 2=PM
V - RPM	1=3, 2=4, 3=5
R - REPLICATIONS	1=1st, 2=2nd

TABLE 38. - MEAN DRT PERFORMANCE TIME (STD) - ONE-DAY TESTS

A_1* 18.29**	A_2 18.76	A_3 18.53	
R_1 18.97	R_2 18.08		
S_1 16.23	S_2 17.61	S_3 21.42	S_4 18.84
T_1 18.44	T_2 18.61		
V_1 18.62	V_2 18.53	V_3 18.43	
GRAND MEAN 18.52457			

* See Table 37 for Code
** Mean Time in Seconds per 25 Lights

TABLE 39. - DRT PERFORMANCE TIME - NEWMAN-KUELS ANALYSIS OF "A" FACTOR (STD MODE) - ONE-DAY TESTS

	POST-HUB	POST-30'	A_1	A_3	A_2	PRE-HUB
POST-HUB	----	37.2*	71.12**	82.37**	93.41**	109.08**
POST-30'		----	33.8*	45.05*	56.09**	71.76**
A_1			----	11.25	22.29	37.96*
A_3				----	11.04	26.71
A_2					----	15.67
PRE-HUB						----

** Significant at the .01 Level
* Significant at the .05 Level

TABLE 40. - DRT RESPONSES ANALYSIS OF VARIANCE - THREE-DAY TEST (STD)

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBABILITY
S	21.08406	3	7.02802		
T	0.00224	2	0.00112	0.001	---
ST	5.09992	6	0.84999		
R	2.85546	2	1.42773	3.274	< .2
SR	2.62435	6	0.43739		
TR	1.74225	4	0.43556	1.470	---
STR	3.55635	12	0.29636		
TOTAL	36.96453	35			

CODE-FACTORS	LEVELS
S - SUBJECTS	1=A, 2=B, 3=F, 4=G
T - STATIONS	1=Hub, 2=30', 3=78'
R - DAYS	1=Day 1, 2=Day 2, 3=Day 3

TABLE 41. - DRT MEAN RESPONSES - THREE-DAY TEST (STD)

R_1* 26.41**	R_2 26.68	R_3 27.09	
S_1 26.16	S_2 27.03	S_3 27.83	S_4 25.88
T_1 26.73	T_2 26.72	T_3 26.74	

* See Table 40 for Code
** Mean Responses per 25 Lights

TABLE 42. - DRT PERFORMANCE TIME ANALYSIS OF VARIANCE - *THREE-DAY TEST* (*STD*)

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBABILITY
S*	210.55020	3	70.18340		
T	0.44951	2	0.22476	0.662	----
ST	2.03698	6	0.33950		
R	0.19471	2	0.09736	0.209	----
SR	2.79476	6	0.46579		
TR	1.79615	4	0.44904	0.610	----
STR	8.83514	12	0.73626		
TOTAL	226.65741	35			

* SEE TABLE 40 FOR CODE

TABLE 43. - MEAN DRT PERFORMANCE TIMES - THREE-DAY TEST (STD)

R_1* 16.79**	R_2 16.72	R_3 16.9	
S_1 13.71	S_2 15.21	S_3 18.72	S_4 19.56
T_1 16.7	T_2 16.75	T_3 16.96	
GRAND MEAN 16.80081			

* See Table 40 for Code
** **Mean Time in Seconds per 25 Lights**

TABLE 44. - DRT RESPONSES ANALYSIS OF VARIANCE - THREE-DAY TEST (CCC)

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBABILITY
S	55.24313	3	18.41437		
A	0.52040	2	0.26020	0.392	----
SA	3.98328	6	0.66388		
R	3.18437	2	1.59218	1.536	----
SR	6.21958	6	1.03660		
AR	2.87501	4	0.71875	7.200	<.005
SAR	1.19794	12	0.09983		
TOTAL	73.22366	35			

CODE - FACTOR	LEVEL
S - SUBJECT	1=A, 2=B, 3=F, 4=G
A - STATIONS	1=Hub, 2-30', 3=78'
r - DAYS	1-Day 1, 2=Day 2, 3=Day 3

TABLE 45. - MEAN DRT RESPONSES - THREE-DAY TEST (CCC)

A_1* 27.65**	A_2 27.72	A_3 27.93	
R_1 27.48	R_2 27.65	R_3 28.18	
S_1 26.74	S_2 27.19	S_3 29.89	S_4 27.25
GRAND MEAN 27.76720			

* See Table 44 for Code
** Mean Responses per 25 Lights

TABLE 46. - DRT PERFORMANCE TIME ANALYSIS OF VARIANCE - THREE-DAY TEST (CCC)

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBABILITY
S	219.04651	3	73.01550		
A	24.21544	2	12.10772	1.049	----
SA	69.26370	6	11.54395		
R	1.69044	2	0.84522	0.130	----
SR	38.93860	6	6.48977		
AR	18.44153	4	4.61038	2.861	$< .1$
SAR	19.33778	12	1.61148		
TOTAL	390.93359	35			

*See Table 44 for Code

TABLE 47. - MEAN DRT PERFORMANCE TIME - THREE-DAY TEST (CCC)

A_1* 27.88**	A_2 25.93	A_3 26.51	
R_1 26.48	R_2 26.98	R_3 26.87	
S_1 23.47	S_2 25.35	S_3 28.82	S_4 29.45
GRAND MEAN 26.77496			

* See Table 44 for Code
** **Mean Time in Seconds per 25 Lights**

TABLE 48. - DRT RESPONSES ANALYSIS OF VARIANCE - THREE-DAY TEST (CR)

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBABILITY
S	47.62416	3	15.87472		
A	4.60454	2	2.30227	1.628	----
SA	8.43743	6	1.41457		
B	2.71079	2	1.35540	2.377	< .2
SB	3.42059	6	0.57010		
AB	3.40893	4	0.85223	1.001	----
SAB	10.21842	12	0.85154		
R	1.88824	1	1.88824	10.599	< .05
SR	0.53445	3	0.17815		
AR	0.47569	2	0.23784	1.270	----
SAR	1.12359	6	0.18727		
BR	0.36711	2	0.18355	0.373	----
SBR	2.95065	6	0.49178		
ABR	0.83091	4	0.20773	0.558	----
SABR	4.46935	12	0.37245		
TOTAL	93.11473	71			

CODE - FACTORS

S - SUBJECTS 1=A, 2=B, 3=F, 4=G
A - STATIONS 1=HUB, 2=30', 3=78'
B - DAYS 1=1st, 2=2nd, 3=3rd
R - REPLICATION 1=1st, 2=2nd

TABLE 49. - MEAN DRT RESPONSES - THREE-DAY TEST (CR)

A_1* 26.74**	A_2 27.25	A_3 26.69	
B_1 26.65	B_2 26.91	B_3 27.12	
R_1 26.73	R_2 27.06		
S_1 26.60	S_2 27.68	S_3 27.6	S_4 25.7
GRAND MEAN 26.89359			

* See Table 48 for Code
** Mean **Responses per 25 Lights**

TABLE 50. - DRT PERFORMANCE TIME ANALYSIS OF VARIANCE - THREE-DAY TEST (CR)

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBABILITY
S	560.80811	3	186.93604		
A	5.43314	2	2.71657	2.084	----
SA	7.81972	6	1.30329		
B	0.81302	2	0.40651	0.591	----
SB	4.12497	6	0.68749		
AB	3.14323	4	0.78581	0.656	----
SAB	14.37205	12	1.19767		
R	8.57677	1	8.57677	2.353	----
SR	10.93570	3	3.64523		
AR	3.96827	2	1.98414	1.706	----
SAR	6.97688	6	1.16281		
BR	0.09772	2	0.04886	0.072	----
SBR	4.07714	6	0.67952		
ABR	1.40951	4	0.35238	1.394	----
SABR	3.03353	12	0.25279		
TOTAL	635.58813	71			

See Table 48 for Code

TABLE 51. - MEAN DRT PERFORMANCE TIME - THREE-DAY TEST (CR)

A_1* 17.05**	A_2 17.63	A_3 17.63	
B_1 17.52	B_2 17.29	B_3 17.51	
R_1 17.09	R_2 17.78		
S_1 13.89	S_2 15.53	S_3 20.07	S_4 20.26
GRAND MEAN 17.43762			

* See Table 48 for Code
** Mean Time in Seconds per 25 Lights

TABLE 52. - DRT RESPONSES ANALYSIS OF VARIANCE - THREE-DAY TEST (AD)

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBABILITY
S	120.77362	3	40.25787		
A	20.44260	1	20.44260	13.470	<.05
SA	4.55281	3	1.51760		
B	3.12063	2	1.56032	0.915	---
SB	10.22853	6	1.70475		
AB	2.14146	2	1.07073	0.236	---
SAB	27.17435	6	4.52906		
R	5.92368	3	1.97456	0.549	---
SR	32.34590	9	3.59399		
AR	2.43614	3	0.81205	0.851	---
SAR	8.58342	9	0.95371		
BR	22.00354	6	3.66726	2.528	<.1
SBR	26.11043	18	1.45058		
ABR	17.71602	6	2.95267	1.352	---
SABR	39.29784	18	2.18321		
TOTAL	342.85034	95			

* See Table 48 for Code

TABLE 53. - MEAN DRT RESPONSES - THREE-DAY TEST (AD)

A_1* 27.10**	A_2 27.96		
B_1 27.46	B_2 27.41	B_3 27.72	
R_1 27.5	R_2 27.86	R_3 27.54	R_4 27.20
S_1 27.42	S_2 27.75	S_3 29.11	S_4 25.83
GRAND MEAN 27.55937			

* See Table 48 for Code
** Mean Responses per 25 Lights

TABLE 54. - DRT PERFORMANCE TIMES ANALYSIS OF VARIANCE - THREE-DAY TEST (AD)

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBABILITY
S *	222.86458	3	74.28819		
A	123.76041	1	123.76041	7.811	< .1
SA	47.53125	3	15.84375		
B	203.06250	2	101.53125	19.905	< .005
SB	30.60416	6	5.10069		
AB	0.39583	2	0.19792	0.007	---
SAB	158.93750	6	26.48958		
R	82.61458	3	27.53819	4.595	< .05
SR	53.92708	9	5.99190		
AR	3.61458	3	1.20486	0.263	---
SAR	41.26041	9	4.58449		
BR	19.35416	6	3.22569	0.880	---
SBR	65.97916	18	3.66551		
ABR	4.85417	6	0.80903	0.242	---
SABR	60.14583	18	3.34143		
TOTAL	1113.90479	95			

* See Table 48 for Code

TABLE 55. - MEAN DRT PERFORMANCE TIME - THREE-DAY TEST (AD)

A_1* 28.1**	A_2 30.17		
B_1 31.0	B_2 28.56	B_3 27.84	
R_1 30.25	R_2 29.5	R_3 28.58	R_4 28.21
S_1 26.71	S_2 28.75	S_3 28.88	S_4 31.21
GRAND MEAN 29.03125			

*See Table 48 for Code

**** Mean Time in Seconds per 25 Lights**

TABLE 56. - DRT PERFORMANCE TIME - NEWMAN-KUELS ANALYSIS OF "B" FACTOR - THREE-DAY TEST (AD)

	B_3	B_2	PRE	B_1
B_3	---	23.	50.04	101**
B_2		---	27.04	78*
PRE			---	50.96*
B_1				---

** Significant at .01 Level

* Significant at .05 Level

TABLE 57. - DRT RESPONSES ANALYSIS OF VARIANCE - SEVEN-DAY TEST (STD)

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBAB-ILITY
S	160.67873	3	53.55957		
B	6.01912	2	3.00956	2.284	< .2
SB	7.90334	6	1.31722		
A	2.23133	2	1.11567	1.370	---
SA	4.88367	6	0.81395		
BA	2.11245	4	0.52811	2.050	< .2
SBA	3.08987	12	0.25749		
R	4.22878	4	1.05719	1.270	---
SR	9.19811	12	0.76651		
BR	7.98524	8	0.99816	2.218	< .1
SBR	10.80053	24	0.45002		
AR	6.12806	8	0.76601	2.534	< .05
SAR	7.25270	24	0.30220		
BAR	8.16853	16	0.51053	1.072	---
SBAR	22.83904	48	0.47581		
TOTAL	263.51929	179			

* See TABLE 81 for Code

TABLE 58. - MEAN DRT RESPONSES - SEVEN-DAY TEST (STD)

A1* 27.39**	A2 27.16	A3 27.12		
B1 27.29	B2 27.01	B3 27.49		
R1 27.32	R2 27.3	R3 27.16	R4 27.47	R5 26.88
S1 27.13	S2 28.86	S3 26.35	S4 26.7	
GRAND MEAN 27.24751				

* See Table 81 for Code
** Mean Performance Time in Seconds per 25 Lights

TABLE 59. - DRT RESPONSES - NEWMAN-KUELS ANALYSIS OF "B" FACTOR - SEVEN-DAY TEST (STD)

	B2	B1	B3	PRE
B2	--	16.98	28.78	61.*
B1		--	11.8	44.02*
B3			--	32.22
PRE				—

*Significant at .05 Level

TABLE 60. - DRT PERFORMANCE TIME ANALYSIS OF VARIANCE - SEVEN-DAY TEST (STD)

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBAB-ILITY
S	555.54541	3	185.18179		
B	61.97572	2	30.98785	22.814	< .005
SB	8.14936	6	1.35823		
A	4.37868	2	2.18934	3.036	< .2
SA	4.32568	6	0.72095		
BA	2.29452	4	0.57363	.642	---
SBA	10.71963	12	0.89330		
R	1.30556	4	0.32639	1.553	---
SR	2.52185	12	0.21015		
BR	1.93138	8	0.24142	.895	---
SBR	6.47170	24	0.26965		
AR	3.30184	8	0.41273	2.027	< .1
SAR	4.88674	24	0.20361		
BAR	3.77007	16	0.23563	1.461	< .2
SBAR	7.73960	48	0.16124		
TOTAL	679.31641	179			

See Table 81 for Code

TABLE 61. - MEAN DRT PERFORMANCE TIME - SEVEN-DAY TEST (STD)

A_1* 15.21*	A_2 15.37	A_3 15.59		
B_1 16.16	B_2 15.28	B_3 14.74		
R_1 15.45	R_2 15.53	R_3 15.36	R_4 15.35	R_5 15.28
S_1 13.11	S_2 14.48	S_3 16.21	S_4 17.76	
GRAND MEAN 15.39210				

* See Table 81 for Code
** Mean Performance Time in Seconds per 25 Lights

TABLE 62. - DRT PERFORMANCE TIME - NEWMAN-KUELS ANALYSIS OF "B" FACTOR - SEVEN-DAY TEST (STD)

	B_3	PRE	B_2	B_1
B_3	--	23.36	32.31	85.4**
PRE		--	8.95	62.04**
B_2			--	53.09**
B_1				--

**Significant at .01 Level

TABLE 63. - DRT RESPONSES ANALYSIS OF VARIANCE - SEVEN-DAY TEST (30- AND 78-FT STATIONS) (CCC)

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBABILITY
S*	36.14648	3	12.04883		
B	2.45094	2	1.22547	0.449	---
SB	16.39052	6	2.73175		
A	10.33757	1	10.33757	19.270	<.025
SA	1.60936	3	0.53645		
BA	4.39067	2	2.19534	1.580	---
SBA	8.33632	6	1.38939		
O	4.29209	4	1.07302	0.807	---
SO	15.95038	12	1.32920		
BO	2.29071	8	0.28634	0.220	---
SBO	31.15997	24	1.29833		
AO	2.89218	4	0.72304	0.822	---
SAO	10.55849	12	0.87987		
BAO	9.45099	8	1.18137	0.678	---
SBAO	41.78235	24	1.74093		
R	0.37527	1	0.37527	0.348	---
SR	3.23849	3	1.07950		
BR	2.62415	2	1.31207	1.788	---
SBR	4.40335	6	0.73389		
AR	0.00274	1	0.00274	0.001	---
SAR	6.27338	3	2.09113		
BAR	7.71311	2	3.85655	2.453	<.2
SBAR	9.43207	6	1.57201		
OR	3.48234	4	0.87058	0.787	---

TABLE 63. - DRT RESPONSES ANALYSIS OF VARIANCE - SEVEN-DAY TEST. (30- AND 78-FT STATIONS) (CCC) - continued

SOR	13.27350	12	1.10612		
BOR	6.09418	8	0.76177	0.480	---
SBOR	38.04749	24	1.58531		
AOR	3.52935	4	0.88234	1.555	---
SAOR	6.80870	12	0.56739		
BAOR	1.82297	8	0.22787	0.220	---
SBAOR	24.85464	24	1.03561		
TOTAL	330.01392	239			

*See Table 81 for Code

TABLE 64. - MEAN DRT RESPONSES - SEVEN-DAY TEST
(30- AND 78-FT STATIONS - CCC)

A_1* 27.91**	A_2 27.49			
B_1 27.68	B_2 27.57	B_3 27.84		
O_1 27.53	O_2 27.59	O_3 27.79	O_4 27.76	O_5 27.85
R_1 27.67	R_2 27.73			
S_1 27.81	S_2 27.2	S_3 27.51	S_4 28.25	
GRAND MEAN 27.69493				

* See Table 81 for Code
** Mean Responses per 25 Lights

TABLE 65. - DRT PERFORMANCE TIME ANALYSIS OF VARIANCE - SEVEN-DAY TEST (30- AND 78-FT STATIONS - CCC)

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBABILITY
S*	1792.79785	3	597.59912		
B	191.12039	2	95.56020	18.503	< .005
SB	30.98767	6	5.16461		
A	4.26660	1	4.26660	0.864	---
SA	14.80941	3	4.93647		
BA	5.03333	2	2.51666	0.587	---
SBA	25.70676	6	4.28446		
O	23.63322	4	5.90831	6.402	< .01
SO	11.07361	12	0.92280		
BO	5.95810	8	0.74476	0.506	---
SBO	35.32622	24	1.47193		
AO	12.44937	4	3.11234	2.963	< .1
SAO	12.60533	12	1.05044		
BAO	22.81941	8	2.85243	1.289	---
SBAO	53.10905	24	2.21288		
R	0.59805	1	0.59805	0.468	---
SR	3.83244	3	1.27748		
BR	2.57400	2	1.28700	2.043	---
SBR	3.77888	6	0.62981		
AR	1.06403	1	1.06403	1.749	---
SAR	1.82430	3	0.60810		
BAR	4.01400	2	2.00700	2.848	< .2
SBAR	4.22857	6	0.70476		
OR	6.78752	4	1.69688	2.221	< .2
SOR	9.16814	12	0.76401		
BOR	7.35289	8	0.91911	0.586	---
SBOR	37.62395	24	1.56766		
AOR	0.99078	4	0.24770	0.399	---
SAOR	7.44498	12	0.62041		
BAOR	2.64506	8	0.33063	0.321	---
SBAOR	24.68253	24	1.02844		
TOTAL	2360.30322	239			

See Table 81 for Code

TABLE 66. - MEAN DRT PERFORMANCE TIME - SEVEN-DAY TEST
(30- AND 78-FT STATIONS - CCC)

A_1* 23.49**	A_2 23.74			
B_1 24.80	B_2 23.40	B_3 22.65		
O_1 23.24	O_2 23.35	O_3 23.63	O_4 23.68	O_5 24.19
R_1 23.58	R_2 23.66			
S_1 20.4	S_2 21.6	S_3 27.21	S_4 25.22	
GRAND MEAN 23.61115				

*See Table 81 for Code
**Mean Time in Seconds per 25 Lights

TABLE 67. - DRT PERFORMANCE TIME - NEWMAN-KUELS ANALYSIS OF "B" FACTOR - SEVEN-DAY TEST (30- AND 78-FT STATIONS - CCC)

	B_3	B_2	PRE	B_1
B_3	---	60.38	146.**	172.**
B_2		---	85.62*	111.62*
PRE			---	26.
B_1				--

* Significant at the .05 Level
** Significant at the .01 Level

TABLE 68. - DRT PERFORMANCE TIME - NEWMAN-KUELS ANALYSIS OF "O" FACTOR - SEVEN-DAY TEST (30- AND 78-FT STATIONS - CCC)

	O_1	O_2	O_3	O_4	O_5
O_1	--	5.34	18.86	20.84	45.34**
O_2		--	13.52	15.5	40. **
O_3			--	1.98	26.48*
O_4				--	24.5 *
O_5					--

* Significant at the .05 Level
**Significant at the .01 Level

TABLE 69. - DRT RESPONSES ANALYSIS OF VARIANCE - SEVEN-DAY TEST (CCC)

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBAB-ILITY
S*	30.71767	3	10.23922		
B	2.81559	2	1.40779	.504	--
SB	16.74739	6	2.79123		
A	4.12662	2	2.06331	1.476	--
SA	8.38280	6	1.39713		
BA	2.75616	4	0.68904	1.173	--
SBA	7.04454	12	0.58705		
R	3.41657	4	0.85414	3.317	< .05
SR	3.08940	12	0.25745		
BR	10.39787	8	1.29973	2.448	< .05
SBR	12.74016	24	0.53084		
AR	4.16077	8	0.52010	.846	--
SAR	14.73971	24	0.61415		
BAR	7.20856	16	0.45053	.773	--
SBAR	27.97484	48	0.58281		
TOTAL	156.31854	179			

* See Table 81 for Code

TABLE 70. - MEAN DRT RESPONSES - SEVEN-DAY TEST (CCC)

A_1* 27.58**	A_2 27.84	A_3 27.48		
B_1 27.54	B_2 27.54	B_3 27.81		
R_1 27.84	R_2 27.51	R_3 27.73	R_4 27.56	R_5 27.5
S_1 27.58	S_2 27.31	S_3 27.32	S_4 28.32	
GRAND MEAN 27.63298				

* See Table 81 for Code

** Mean Responses per 25 Lights

TABLE 71. - DRT PERFORMANCE TIME ANALYSIS OF VARIANCE - SEVEN-DAY TEST (CCC)

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBAB-ILITY
S *	1505.50000	3	501.83325		
B	251.79050	2	125.89525	27.943	<.001
SB	27.03247	6	4.50541		
A	22.76341	2	11.38171	2.099	
SA	32.52875	6	5.42146		
BA	30.85239	4	7.71310	1.474	---
SBA	62.77133	12	5.23094		
R	28.63295	4	7.15824	4.365	<.025
SR	19.67824	12	1.63985		
BR	8.21942	8	1.02743	.841	---
SBR	29.29857	24	1.22077		
AR	8.36425	8	1.04553	1.360	---
SAR	18.44699	24	0.76862		
BAR	11.35027	16	0.70939	.913	---
SBAR	37.27855	48	0.77664		
TOTAL	2094.50586	179			

* See Table 81 for Code

TABLE 72. - MEAN DRT PERFORMANCE TIME - SEVEN-DAY TEST (CCC)

A_1* 22.89**	A_2 23.47	A_3 23.76		
B_1 24.92	B_2 23.13	B_3 22.06		
R_1 24.05	R_2 23.54	R_3 23.30	R_4 23.02	R_5 22.95
S_1 20.1	S_2 21.0	S_3 26.94	S_4 25.44	
GRAND MEAN 23.37097				

* See Table 81 for Code
** Mean Time in Seconds per 25 Lights

TABLE 73. - DRT PERFORMANCE TIME - NEWMAN-KUELS ANALYSIS OF "B" FACTOR - SEVEN-DAY TEST (CCC)

	B_3	B_2	PRE	B_1
B_3	--	64.11*	145.07**	171.39**
B_2		--	80.96*	107.28*
PRE			--	26.32
B_1				--

** Significant at .01 Level
* Significant at .05 Level

TABLE 74. - DRT PERFORMANCE TIME - NEWMAN-KUELS ANALYSIS OF "R" FACTOR - SEVEN-DAY TEST (CCC)

	1	2	3	4	5
1	--	2.36	12.65	21.12	39.46*
2		--	10.29	18.76	37.1 *
3			--	8.4	26.81
4				--	18.34
5					--

* Significant at the .05 Level

TABLE 75. - DRT PERFORMANCE TIME ANALYSIS OF VARIANCE - SEVEN-DAY TEST (CR)

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBABILITY
S *	240.82074	3	80.27357		
B	13.37360	2	6.68680	7.342	< .025
SB	5.46491	6	0.91082		
A	15.40507	2	7.70254	22.935	< .005
SA	2.01506	6	0.33584		
BA	0.69641	4	0.17410	0.957	--
SBA	2.18300	12	0.18192		
R	0.01390	1	0.01390	0.143	--
SR	0.29094	3	0.09698		
BR	0.30500	2	0.15250	1.568	--
SBR	0.58335	6	0.09723		
AR	0.02084	2	0.01042	0.090	--
SAR	0.69170	6	0.11528		
BAR	1.80385	4	0.45096	10.561	< .001
SBAR	0.51242	12	0.04270		
TOTAL	284.17920	71			

*See Table 81 for Code

TABLE 76. - MEAN DRT PERFORMANCE TIME - SEVEN-DAY TEST (CR)

A_1* 14.76**	A_2 15.44	A_3 15.88	
B_1 15.85	B_2 15.45	B_3 14.80	
R_1 15.37	R_2 15.34		
S_1 13.15	S_2 14.27	S_3 16.04	S_4 17.97
GRAND MEAN 15.35832			

* See Table 81 for Code
** **Mean Time in Seconds for 25 Lights**

TABLE 77. - DRT PERFORMANCE TIME - NEWMAN-KUELS ANALYSIS OF "B" FACTOR - SEVEN-DAY TEST (CR)

	B_3	PRE	B_2	B_1
B_3	--	13.3	14.89	25.19*
PRE		--	1.59	11.89
B_2			--	10.31
B_1				--

* Significant at the .05 Level

TABLE 78. - DRT PERFORMANCE TIME - NEWMAN-KUELS ANALYSIS OF "A" FACTOR - SEVEN-DAY TEST (CR)

	A_1	A_2	A_3	
A_1	--	16.43**	26.98**	
A_2		--	10.55*	
A_3			--	

** Significant at the .01 Level
* Significant at the .05 Level

TABLE 79. - DRT RESPONSES ANALYSIS OF VARIANCE - SEVEN-DAY TEST (CR)

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBAB-ILITY
S	78.67383	3	26.22461		
B	1.01300	2	0.50650	1.414	---
SB	2.14911	6	0.35819		
A	0.64590	2	0.32295	1.186	---
SA	1.63318	6	0.27220		
BA	1.02730	4	0.25682	1.573	---
SBA	1.95953	12	0.16329		
R	1.06580	1	1.06580	2.360	---
SR	1.35482	3	0.45161		
BR	0.81999	2	0.40999	1.780	---
SBR	1.38158	6	0.23026		
AR	1.27156	2	0.63578	4.160	<.1
SAR	0.91710	6	0.15285		
BAR	2.58315	4	0.64579	1.175	---
SBAR	6.59695	12	0.54975		
TOTAL	103.09270	71			

* See Table 81 for Code

TABLE 80. - MEAN DRT RESPONSES - SEVEN-DAY TEST (CR)

A_1* 27.30**	A_2 27.38	A_3 27.43	
B_1 27.16	B_2 27.35	B_3 27.52	
R_1 27.22	R_2 27.52		
S_1 27.01	S_2 29.19	S_3 26.63	S_4 26.69
GRAND MEAN 27.34998			

* See Table 81 for Code
** Mean Responses per 25 Lights

TABLE 81. - DRT RESPONSES ANALYSIS OF VARIANCE (30- AND 78-FT STATIONS - STD) - SEVEN-DAY TEST

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBABILITY
S	246.60852	3	82.20284		
B	5.96919	2	2.98459	1.562	---
SB	11.46276	6	1.91046		
A	0.06633	1	0.06633	.135	---
SA	1.47458	3	0.49153		
BA	4.11542	2	2.05771	3.064	<.2
SBA	4.02992	6	0.67165		
O	6.10609	4	1.52652	2.016	<.2
SO	9.08574	12	0.75714		
BO	8.64478	8	1.08060	.898	---
SBO	28.89397	24	1.20391		
AO	2.50172	4	0.62543	.506	---
SAO	14.81964	12	1.23497		
BAO	12.32191	8	1.54024	2.366	<.05
SBAO	15.62479	24	0.65103		
R	1.06250	1	1.06250	1.113	---
SR	2.86271	3	0.95424		
BR	2.15807	2	1.07903	2.372	<.2
SBR	2.72922	6	0.45487		
AR	4.16847	1	4.16847	25.411	<.025
SAR	0.49213	3	0.16404		
BAR	1.27413	2	0.63707	.384	---
SBAR	9.96068	6	1.66011		
OR	5.34163	4	1.33541	.744	---

TABLE 81. - DRT RESPONSES ANALYSIS OF VARIANCE (30- AND 78-FT STATIONS - STD) - SEVEN-DAY TEST - continued

SOR	21.53267	12	1.79439		
BOR	9.55937	8	1.19492	1.768	< .2
SBOR	16.21561	24	0.67565		
AOR	5.02075	4	1.25519	2.337	<.2
SAOR	6.44396	12	0.53700		
BAOR	15.58439	8	1.94805	1.694	<.2
SBAOR	27.59309	24	1.14971		
TOTAL	503.72119	239			

CODE - FACTORS	LEVELS
S - SUBJECTS	1=A, 2=B, 3=D, 4-G
B - BLOCKS	1-Days 1 + 2, 2=Days 3 - 5, 3= Days 6 + 7
A - STATIONS	1=30', 2=78'
O - ORIENTATIONS	1=Pro-Spin, 2=45° Pro-Spin, 3=Axial, 4=45° Anti-Spin, 5= Anti-Spin
R - REPLICATIONS	1=1st, 2=2nd

TABLE 82. - MEAN DRT RESPONSES - SEVEN-DAY TEST
(30- AND 78-FT STATIONS - STD)

A_1* 27.19**	A_2 27.23			
B_1 27.26	B_2 27.02	B_3 27.23		
O_1 27.16	O_2 26.96	O_3 27.24	O_4 27.33	O_5 26.36
R_1 27.14	R_2 27.29			
S_1 27.11	S_2 29.1	S_3 26.36	S_4 26.4	
GRAND MEAN 27.19852				

* See Table 81 for Code
** Mean Responses per 25 Lights

TABLE 83. - DRT RESPONSES - NEWMAN-KUELS ANALYSIS
OF "B" FACTOR - SEVEN-DAY TEST (STD)

B_2	B_3	B_1	PRE
B_2 ---	17.08	19.08	80.38*
B_3	---	2.00	63.3 *
B_1			61.3 *
PRE			---

* Significant at the .05 Level

TABLE 84. - DRT PERFORMANCE TIME ANALYSIS OF VARIANCE - SEVEN-DAY TEST (30- AND 78-FT STATIONS - STD)

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBAB-ILITY
S *	750.72485	3	250.24161		
B	64.64854	2	32.32426	11.188	< 0.1
SB	17.33527	6	2.88921		
A	2.71150	1	2.71150	1.555	---
SA	5.22958	3	1.74319		
BA	0.30712	2	0.15356	0.154	---
SBA	5.97452	6	0.99575		
O	2.65210	4	0.66302	1.720	---
SO	4.62459	12	0.38538		
BO	2.53381	8	0.31673	0.891	---
SBO	8.53304	24	0.35554		
AO	3.07269	4	0.76817	1.720	---
SAO	5.36064	12	0.44672		
BAO	3.03870	8	0.37984	0.880	---
SBAO	10.35832	24	0.43160		
R	0.14067	1	0.14067	0.485	---
SR	0.87617	3	0.29206		
BR	0.16843	2	0.08421	0.108	---
SBR	4.68571	6	0.78095		
AR	0.91635	1	0.91635	2.677	---
SAR	1.02700	3	0.34233		
BAR	1.85938	2	0.92969	1.369	---
SBAR	4.07487	6	0.67915		
OR	1.22155	4	0.30539	0.374	---
SOR	9.79877	12	0.81656		
BOR	4.81715	8	0.60214	2.667	< .05
SBOR	5.41797	24	0.22575		
AOR	1.39066	4	0.34766	0.660	---
SAOR	6.31641	12	0.52637		
BAOR	5.65466	8	0.70683	1.542	< .2
SBAOR	10.99696	24	0.45821		
TOTAL	946.46460	239			

*See Table 81 for Code

TABLE 85. - MEAN DRT PERFORMANCE TIME - SEVEN-DAY TEST (30- AND 78-FT STATIONS - STD)

A_1* 15.35**	A_2 15.59			
B_1 16.11	B_2 15.43	B_3 14.87		
O_1 15.42	O_2 15.32	O_3 15.58	O_4 15.41	O_5 15.63
R_1 15.44	R_2 15.50			
S_1 13.2	S_2 14.49	S_3 16.41	S_4 17.82	
GRAND MEAN 15.47987				

* See Table 81 for Code
** **Mean Performance Time per 25 Lights**

TABLE 86. - DRT PERFORMANCE TIME - NEWMAN-KUELS ANALYSIS OF "B" FACTOR - SEVEN-DAY TEST (STD)

	B_3	PRE	B_2	B_1
B_3	--	2.07	45.18	99.5*
PRE		---	24.48	78.8*
B_2			---	54.32
B1				---

* Significant at the .05 Level

TABLE 87. - DRT PERFORMANCE TIME ANALYSIS OF VARIANCE - SEVEN-DAY TEST (AD)

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBABILITY
S *	62.63521	3	20.87840		
B	134.07210	2	67.03604	18.747	< .005
SB	21.45506	6	3.57584		
A	8.20060	1	8.20060	14.389	< .05
SA	1.71104	3	0.57035		
BA	4.90388	2	2.45194	5.771	< .05
SBA	2.54927	6	0.42488		
R	1.17180	1	1.17180	2.228	---
SR	1.57794	3	0.52598		
BR	1.32031	2	0.66016	1.619	---
SBR	2.44683	6	0.40780		
AR	1.39398	1	1.39398	1.093	---
SAR	3.82515	3	1.27505		
BAR	0.96458	2	0.48229	1.330	---
SBAR	2.17629	6	0.36271		
TOTAL	250.40395	47			

*See Table 81 for Code

TABLE 88. - MEAN DRT PERFORMANCE TIME - SEVEN-DAY TEST (AD)

A_1* 23.8**	A_2 24.63		
B_1 26.55	B_2 23.40	B_3 22.7	
R_1 24.37	R_2 24.06		
S_1 23.22	S_2 24.71	S_3 23.09	S_4 25.86
GRAND MEAN 24.21831			

* See Table 81 for Code
** Mean Time in Seconds per 25 Lights

TABLE 89. - DRT PERFORMANCE TIME - NEWMAN-KUELS ANALYSIS OF "B" FACTOR - SEVEN-DAY TEST (AD)

	B_3	B_2	B_1	
B_3	--	11.2	61.5**	
B_2		--	50.3**	
B_1			--	

** Significant at the .01 Level

TABLE 90. - DRT RESPONSES ANALYSIS OF VARIANCE - SEVEN-DAY TEST (AD)

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBABILITY
S *	16.65681	3	5.61894		
B	1.77109	2	0.88555	0.731	---
SB	7.26742	6	1.21124		
A	0.28212	1	0.28212	1.869	---
SA	0.45274	3	0.15091		
BA	1.20052	2	0.60026	1.377	---
SBA	2.61547	6	0.43591		
R	0.00521	1	0.00521	0.036	---
SR	0.42716	3	0.14239		
BR	0.01042	2	0.00521	0.028	---
SBR	1.11556	6	0.18593		
AR	0.00241	1	0.00241	0.010	---
SAR	0.75442	3	0.25147		
BAR	1.42981	2	0.71491	8.287	< .025
SBAR	0.51760	6	0.08627		
TOTAL	34.70866	47			

*See Table 81 for Codes

TABLE 91. - MEAN DRT RESPONSES - SEVEN-DAY TEST (AD)

A_1* 26.83*	A_2 26.98		
B_1 26.88	B_2 27.15	B_3 26.69	
R_1 26.92	R_2 26.89		
S_1 27.77	S_2 27.12	S_3 26.26	S_4 26.47
GRAND MEAN 26.90581			

*See Table 81 for Codes
**** Mean Responses per 25 Lights**

TABLE 92. - STROMBERG PERFORMANCE TIME ANALYSIS OF VARIANCE - ONE-DAY TESTS

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBABILITY
S	1280.92188	3	426.97388		
A	107.11263	2	53.55630	9.802	<.025
SA	32.78233	6	5.46372		
B	58.19182	2	29.09590	7.253	<.05
SB	24.06984	6	4.01164		
AB	9.58153	4	2.39538	.519	--
SAB	55.40826	12	4.61736		
C	43.23048	1	43.23048	9.501	<.1
SC	13.65017	3	4.55006		
AC	71.93625	2	35.96812	4.280	<.1
SAC	50.42529	6	8.40421		
BC	4.81538	2	2.40769	.573	--
SBC	25.21283	6	4.20214		
ABC	15.79956	4	3.94989	1.368	--
SABC	34.65688	12	2.88807		
R	14.62962	1	14.62962	3.262	<.2
SR	13.45573	3	4.48524		
AR	33.25288	2	16.62643	2.221	<.2
SAR	30.96979	6	5.16163		
BR	15.34882	2	7.67441	2.508	<.2

TABLE 92. - STROMBERG PERFORMANCE TIME ANALYSIS OF VARIANCE - ONE-DAY TESTS - continued

SBR	18.35733	6	3.05956		
ABR	14.23707	4	3.55927	2.910	< .1
SABR	14.67498	12	1.22291		
CR	7.98058	1	7.98058	2.079	--
SCR	11.51683	3	3.83894		
ACR	16.09041	2	8.04520	3.151	< .2
SACR	15.32113	6	2.55352		
BCR	1.71124	2	0.85562	.216	--
SBCR	23.78362	6	3.96394		
ABCR	24.34943	4	6.08736	2.358	< .2
SABCR	30.97356	12	2.58113		
TOTAL	2114.44434	143			

CODE - FACTORS	LEVELS
S - SUBJECTS	1=A, 2=B, 3=C, 4=D
A - RPM	1=3, 2=3, 3=4
B - ORIENTATIONS	1= Pro-Spin, 2= Axial, 3= Anti-Spin
C - TIME OF DAY	1= AM, 2= PM
R - REPLICATIONS	1= 1st, 2= 2nd

TABLE 93. - STROMBERG PERFORMANCE TIME - ONE-DAY TESTS

A_1* 50.69**	A_2 51.16	A_3 52.71	
B_1 52.35	B_2 50.81	B_3 51.39	
C_1 52.07	C_2 50.97		
R_1 51.84	R_2 51.2		
S_1 46.68	S_2 51.96	S_3 54.79	S_4 52.65
GRAND MEAN 51.52013			

* See Table 92 for Code
** Mean Time in Seconds per Set

TABLE 94. - STROMBERG PERFORMANCE TIME - NEWMAN-KUELS ANALYSIS OF "A" FACTOR - ONE-DAY TESTS

	POST	PRE	A_1	A_2	A_3
POST	--	2.4	87.48*	110.38*	184.48*
PRE		---	85.08**	107.98**	182.08**
A_1			--	22.9	97.*
A_2				--	74.1*
A_3					--

** Significant at the .01 Level
* Significant at the .05 Level

TABLE 95. - STROMBERG PERFORMANCE TIME - NEWMAN-KUELS ANALYSIS OF "B" FACTOR - ONE-DAY TESTS

	B_2	B_3	B_1		
B_2	--	27.9	74.*		
B_3		--	46.1		
B_1				--	

*Significant at the .05 Level

TABLE 96. - STROMBERG PERFORMANCE TIME ANALYSIS OF VARIANCE - THREE-DAY TEST

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBABILITY
S	375.71484	3	125.23828		
A	72.24725	4	18.06181	7.162	< .005
SA	30.26349	12	2.52196		
R	20.66370	1	20.66370	24.015	< .025
SR	2.58137	3	0.86046		
AR	49.27931	4	12.31983	6.491	< .01
SAR	22.77725	12	1.89810		
TOTAL	573.52661	39			

CODE - FACTORS	LEVELS
S - SUBJECTS	1=A, 2=B, 3=F, 4=G
A - RPM TREATMENTS	1= Pre-Warmup, 2= Pre-Baseline, 3= Rotation Warmup, 4= Rotation, 5= Rotation 10 Head Movement
R - REPLICATIONS	1= 1st, 2=2nd

TABLE 97. - STROMBERG PERFORMANCE - THREE-DAY TEST

A_1* 47.82**	A_2 47.97	A_3 51.54	A_4 48.68	A_5 49.22
R_1 49.76	R_2 48.33			
S_1 44.69	S_2 47.87	S_3 50.83	S_4 52.79	
GRAND MEAN 49.04471				

* See Table 96 for Code
** Mean Time in Seconds per Set

TABLE 98. - STROMBERG PERFORMANCE TIME - NEWMAN-KUELS ANALYSIS OF "A" FACTOR - THREE-DAY TEST

	A_1	A_2	A_4	A_5	A_3
A_1	--	1.24	6.85	11.2	29.75**
A_2		--	5.61	9.96	28.51**
A_4			--	4.35	22.9 **
A_5				--	18.55*
A_3					--

** Significant at the .01 Level
* Significant at the .05 Level

TABLE 99. - STROMBERG PERFORMANCE TIME ANALYSIS OF VARIANCE - SEVEN-DAY TEST

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBABILITY
S	603.43652	3	201.14551		
A	19.85455	2	9.92728	5.761	$< .05$
SA	10.33937	6	1.72323		
B	42.19127	2	21.09563	1.959	--
SB	64.60229	6	10.76705		
AB	37.65062	4	9.41265	2.134	$< .2$
SAB	52.92317	12	4.41026		
R	0.13954	1	0.13954	.135	--
SR	3.10727	3	1.03576		
AR	9.15898	2	4.57949	.620	--
SAR	44.34431	6	7.39072		
BR	0.60545	2	0.30272	.276	--
SBR	6.57099	6	1.09517		
ABR	1.83987	4	0.45997	.224	--
SABR	24.61971	12	2.05164		
TOTAL	921.38257	71			

CODE -FACTOR	LEVEL
S - SUBJECTS	1=A, 2=B, 3=D, 4=G
A - HEAD MOVEMENTS	1=0, 2=5, 3=10
B - BLOCKS	1=Days 1+2, 2=Days 3-5, 3=Days 6+7
R - REPLICATIONS	1=1st, 2=2nd

TABLE 100. - STROMBERG PERFORMANCE TIME - SEVEN-DAY TEST

A_1* 48.7**	A_2 47.6	A_3 47.59	
B_1 48.9	B_2 47.95	B_3 47.03	
R_1 47.91	R_2 48.01		
S_1 44.33	S_2 47.72	S_3 47.38	S_4 52.43
GRAND MEAN 47.96150			

* See Table 99 for Code
** Mean Time in Seconds per set

TABLE 101. - STROMBERG PERFORMANCE - NEWMAN-KUELS ANALYSIS OF "A" FACTOR - SEVEN-DAY TEST

	A_1	A_2	A_3	
A_1	--	.20	26.75N.S.	
A_2		--	26.55*	
A_3			--	

* Significant at the .05 Level
N.S. Not Significant according to Newman-Kuels analysis which required a value of >27.86, however F Ratio indicates <.05.

TABLE 102. - STROMBERG PERFORMANCE - NEWMAN-KUELS ANALYSIS OF "B" FACTOR - SEVEN-DAY TEST

	PRE	B_3	B_2	B_1
PRE	---	37.30	59.33	82.3*
B_3		--	22.03	45.0
B_2			--	22.97
B_1				--

*Significant at the .05 level

TABLE 103. - MODIFIED STROMBERG PERFORMANCE TIME ANALYSIS OF VARIANCE - ONE-DAY TESTS

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBABILITY
S	340.57446	3	280.19141		
A	0.59043	2	0.29522	.101	---
SA	17.59450	6	2.93242		
B	47.40176	1	47.40176	9.846	< .1
SB	14.44225	3	4.81408		
AB	83.29904	2	41.64952	11.406	<.01
SAB	21.90953	6	3.65159		
R	20.67220	1	20.67220	3.150	< .2
SR	19.68890	3	6.56297		
AR	2.08622	2	1.04311	.101	---
SAR	61.81520	6	10.30253		
BR	8.41675	1	8.41675	3.536	< .2
SBR	7.14055	3	2.38018		
ABR	14.55133	2	7.27567	1.941	---
SABR	22.49368	6	3.74895		
TOTAL	1182.67554	47			

CODE - FACTORS

S - SUBJECTS	1=A, 2=B, 3=C, 4=D
A - RPM	1=3, 2=4, 3=5
B - TIME OF DAY	1=AM , 2=PM
R - REPLICATIONS	1=1st, 2-2nd

TABLE 104. - MODIFIED STROMBERG PERFORMANCE TIME - ONE-DAY TESTS

A_1* 59.31**	A_2 59.1	A_3 59.05	
B_1 58.16	B_2 60.15		
R_1 59.81	R_2 58.5		
S_1 52.3	S_2 59.48	S_3 63.34	S_4 61.48
GRAND MEAN 59.15205			

* See Table 103 for Code
** Mean Time in Seconds per Set

TABLE 105. - MODIFIED STROMBERG PERFORMANCE - NEWMAN-KUELS ANALYSIS OF "A" FACTOR - ONE-DAY TESTS

	POST	A_3	A_2	PRE	A_1
POST	--	88.96*	89.76**	92.08**	93.06**
A_3		--	.8	3.12	4.1
A_2			--	2.32	3.3
PRE					.98
A_1					--

** Significant at the .01 Level
* Significant at the .05 Level

TABLE 106. - PURSUIT ROTOR PERFORMANCE ANALYSIS OF VARIANCE - THREE-DAY TEST

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBABILITY
S	175.75343	3	58.58447		
H	106.52310	2	53.26155	4.373	<.1
SH	73.07668	6	12.17945		
R	5.40614	2	2.70307	1.300	--
SR	12.47669	6	2.07945		
HR	10.03470	4	2.50867	2.134	<.2
SHR	14.10435	12	1.17536		
TOTAL	397.37451	35			

CODE - FACTORS	LEVELS
S - SUBJECTS	1=A, 2=B, 3=F, 4=G
H - HEAD MOVEMENTS	1=0, 2=5, 3=10
R - REPLICATIONS	1= 1st, 2=2nd, 3-3rd

TABLE 107. - PURSUIT ROTOR PERFORMANCE TIME - THREE-DAY TEST

H_1* 49.49**	H_2 53.64	H_3 50.92	
R_1 50.97	R_2 51.88	R_3 51.19	
S_1 51.65	S_2 47.95	S_3 54.14	S_4 51.66
GRAND MEAN 51.34914			

* See Table 106 for Code
**Mean Time in Seconds for 3 - 20 Second Trials

TABLE 108. - PURSUIT ROTOR PERFORMANCE - NEWMAN-KUELS ANALYSIS OF "H" FACTOR - THREE-DAY TEST

	PRE	H_1	H_3	POST	H_2
PRE	---	113.96**	131.07**	153.72**	163.72**
H_1		---	17.11	39.76	49.76
H_3			---	22.65	32.65
POST				---	10.
H_2					---

**Significant at the .01 Level

TABLE 109. - PURSUIT ROTOR PERFORMANCE ANALYSIS OF VARIANCE - SEVEN-DAY TEST

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBABILITY
S	701.30005	3	233.76668		
B	370.20020	2	185.10010	9.212	<.025
SB	120.55328	6	20.09221		
H	26.19070	2	13.09535	2.244	<.20
SH	35.01886	6	5.83648		
BH	27.50957	4	6.87739	.891	---
SBH	92.61604	12	7.71800		
R	5.90355	2	2.95177	1.727	---
SR	10.25585	6	1.70931		
BR	1.60743	4	0.40186	.140	---
SBR	34.31180	12	2.85932		
HR	4.83144	4	1.20786	.332	---
SHR	43.61728	12	3.63477		
BHR	10.78979	8	1.34872	.706	---
SBHR	45.87975	24	1.91166		
TOTAL	1530.58423	107			

CODE -FACTORS

S -	SUBJECTS	1=A, 2=B, 3=D, 4=G
B -	BLOCKS	1=Days 1+2, 2=Days 3-5, 3=Days 6+7
H -	HEAD MOVEMENTS	1=0, 2=5, 3=10
R -	REPLICATIONS	1=1st, 2=2nd, 3=3rd

TABLE 110. - PURSUIT ROTOR PERFORMANCE TIME - SEVEN-DAY TEST

B_1* 53.21**	B_2 55.04	B_3 57.66	
H_1 54.76	H_2 55.19	H_3 55.96	
R_1 54.95	R_2 55.41	R_3 55.56	
S_1 57.16	S_2 57.04	S_3 50.98	S_4 56.04
GRAND MEAN 55.32161			

*See Table 109 for Code
** Mean Time in Seconds for 3 - 20 Second Trials

TABLE 111. - PURSUIT ROTOR PERFORMANCE - NEWMAN-KUELS ANALYSIS OF "B" FACTOR - SEVEN-DAY TEST

	PRE	B_1	B_2	B_3
PRE	---	157.78**	223.52**	318.07**
B_1		--	65.74	160.29*
B_2			--	94.55*
B_3				--

** Significant at the .01 Level
* Significant at the .05 Level

TABLE 112. - MEMORY DRUM PERFORMANCE ANALYSIS OF VARIANCE - THREE-DAY TEST
(NUMBER CORRECT ON FIRST FOUR TRIALS)

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBABILITY
S	116.53058	3	38.84352		
T	26.30232	3	8.76744	1.577	---
ST	50.02061	9	5.55785		
TOTAL	192.85352	15			

TABLE 113. - MEMORY DRUM PERFORMANCE - THREE-DAY TEST
(MEANS OF CORRECT SCORE FIRST FOUR TRIALS)

S_1*	S_2	S_3	S_4
15.31**	18.67	18.21	22.88
T_1	T_2	T_3	T_4
16.75	18.75	20.25	19.31
GRAND MEAN = 18.76498			

* See Table 112 for Code
** **Means of Correct Scores on First Four Trials**

TABLE 114. - MEMORY DRUM PERFORMANCE ANALYSIS OF VARIANCE - THREE-DAY TEST (TOTAL TRIALS TO CORRECT)

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBABILITY
S*	78.23981	3	26.07993	.907	---
T	9.85626	3	3.28542		
ST	32.58873	9	3.62097		
TOTAL	120.68479	15			

*See Table 112 for Codes

TABLE 115. - MEMORY DRUM PERFORMANCE - THREE-DAY TEST

S_1**	S_2	S_3	S_4
10.38**	7.08	7.79	4.17
T_1	T_2	T_3	T_4
8.12	7.63	7.63	6.04
GRAND MEAN = 7.35312			

* See Table 112 for Codes
** Mean of Total Trials to Correct

TABLE 116. - MEMORY DRUM PERFORMANCE ANALYSIS OF VARIANCE - SEVEN-DAY TEST (NUMBER CORRECT ON FIRST FOUR TRIALS)

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBABILITY
S	1094.11450	3	364.70483		
B	12.76042	1	12.76042	0.374	---
SB	102.28125	3	34.09375		
H	64.77083	2	32.38541	2.681	< .2
SH	72.47916	6	12.07986		
BH	22.02083	2	11.01041	2.690	< .2
SBH	24.56250	6	4.09375		
TOTAL	1392.93901	23			

CODE - FACTORS

S - SUBJECTS 1=A, 2=B, 3=D, 4=G
B - BLOCKS 1=Days 1-3, 2=Days 4-7
H - HEAD MOVEMENTS 1=0, 2=5, 3=10

TABLE 117. - MEMORY DRUM PERFORMANCE - SEVEN-DAY TEST

B_1* 19.5**	B_2 18.04		
H_1 20.5	H_2 19.25	H_3 16.56	
S_1 14.0	S_2 20.83	S_3 11.42	S_4 28.83
GRAND MEAN 18.77083			

* See Table 116 for Code
** Means of Correct Scores on First Four Trials

TABLE 118. - MEMORY DRUM PERFORMANCE ANALYSIS OF VARIANCE - SEVEN-DAY TEST (TRIALS TO CORRECT)

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBABILITY
S*	361.04150	3	120.34717		
B	18.37500	1	18.37500	0.972	---
SB	56.70833	3	18.90277		
H	20.33333	2	10.16666	3.000	<.2
SH	20.33333	6	3.38889		
BH	25.00000	2	12.50000	0.792	
SBH	94.66666	6	15.77778		
TOTAL	596.45776	23			

*See Table 116 for Code

TABLE 119. - MEMORY DRUM PERFORMANCE - SEVEN-DAY TEST

B_1* 9.33**	B_2 7.58		
H_1 8.38	H_2 7.38	H_3 9.63	
S_1 10.25	S_2 5.5	S_3 13.92	S_4 4.17
GRAND MEAN = 8.45833			

* See Table 116 for Code.

** **Mean of Total Trials to Correct**

TABLE 120. - MENTAL ARITHMETIC ANALYSIS OF VARIANCE - THREE-DAY TEST

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBABILITY
S	0.80515	3	0.26838		
A	0.55163	2	0.27582	3.635	< .1
SA	0.45530	6	0.07598		
R	0.09375	1	0.09375	1.231	--
SR	0.22848	3	0.07616		
AR	0.43750	2	0.21875	1.505	--
SAR	0.87197	6	0.14533		
TOTAL	3.44378	23			

CODE - FACTORS / LEVELS

FACTORS	LEVELS
S - SUBJECTS	1=A, 2=B, 3=F, 4=G
A - HEAD MOVEMENTS	1=0, 2=5, 3=10
R - REPLICATIONS	1=1st, 2=2nd

TABLE 121. - MENTAL ARITHMETIC - THREE-DAY TEST

A_1* 2.71**	A_2 2.69	A_3 2.38	
R_1 2.65	R_2 2.53		
S_1 2.31	S_2 2.78	S_3 2.56	S_4 2.72
GRAND MEAN = 2.58917			

* See Table 120 for Code

** Mean Correct Answers for 3 Trial Set

TABLE 122. - MENTAL ARITHMETIC ANALYSIS OF VARIANCE - SEVEN-DAY TEST (CORRECT ANSWERS)

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBABILITY
S	8.11432	3	2.70477		
A	1.88751	2	0.94375	1.858	---
SA	3.04782	6	0.50797		
B	1.07834	2	0.53917	3.140	< .2
SB	1.03032	6	0.17172		
AB	2.08835	4	0.52209	1.796	< .2
SAB	3.48895	12	0.29075		
R	0.55827	1	0.55827	1.118	--
SR	1.49815	3	0.49938		
AR	0.12071	2	0.06036	.300	--
SAR	1.20546	6	0.20091		
BR	0.66821	2	0.33411	.929	--
SBR	2.15796	6	0.35966		
ABR	1.56475	4	0.39119	1.977	< .2
SABR	2.37424	12	0.19785		
TOTAL	30.88329	71			

CODE - FACTORS	LEVELS
S - SUBJECTS	1=A, 2=B, 3=D, 4=G
A - HEAD MOVEMENTS	1=0, 2=5, 3=10
B - BLOCKS	1=Days 1+2, 2=Days 3-5, 3=Days 6+7
R - REPLICATIONS	

TABLE 123. - MENTAL ARITHMETIC - SEVEN-DAY TEST

A_1* 2.75**	A_2 2.35	A_3 2.52	
B_1 2.38	B_2 2.67	B_3 2.58	
R_1 2.45	R_2 2.63		
S_1 2.26	S_2 2.89	S_3 2.16	S_4 2.86
GRAND MEAN 2.54139			

* See Table 122 for Code
** Mean Correct Answers

TABLE 124. - ATAXIA - WOFEC - ANALYSIS OF VARIANCE - ONE-DAY TESTS

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBABILITY
S	794.58325	3	264.86108		
V	31.68750	2	15.84375	.205	---
SV	462.97900	6	77.16316		
O	93.75000	3	31.25000	1.551	---
SO	181.33333	9	20.14815		
VO	122.81250	6	20.46875	.532	---
SVO	692.85400	18	38.49188		
T	165.37500	1	165.37500	9.068	< .1
ST	54.70833	3	18.23610		
VT	31.93750	2	15.96875	1.987	---
SVT	48.22916	6	8.03819		
OT	190.20833	3	63.40277	3.641	< .1
SOT	156.70833	9	17.41203		
VOT	134.22916	6	22.37152	1.047	---
SVOT	384.60400	18	21.36688		
TOTAL	3545.99878	95			

FACTORS	LEVELS
S - SUBJECTS	1=A, 2=B, 3=C, 4=D
V - ROTATION RATES	1=3 RPM, 2=4 RPM, 3=5 RPM
O - ORDER OF TESTING	1-1st, 2=2nd, 3=3rd, 4=4th
T - REPLICATION	1=WOFEC I, 2=WOFEC II

TABLE 125. - ATAXIA - WOFEC - ONE-DAY TESTS

O_1* 8.46**	O_2 7.21	O_3 6.58	O_4 5.75
S_1 10.58	S_2 3.62	S_3 9.00	S_4 4.79
T_1 8.31	T_2 5.69		
V_1 6.28	V_2 7.03	V_3 7.69	
GRAND MEAN 7.00000			

* See Table 124 for Code
Mean Differences from Pre-Test Baseline

TABLE 126. - ATAXIA - SHARPENED ROMBERG - ANALYSIS OF VARIANCE - ONE-DAY TESTS

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBABILITY
S *	21780.72656	3	7260.24219		
V	2358.79150	2	1179.39575	1.148	---
SV	6159.20703	6	1026.53442		
O	8770.22656	3	2923.40869	3.095	< .1
SO	8500.51953	9	944.50195		
VO	809.20825	6	134.86804	.055	---
SVO	43432.71875	18	2412.92871		
TOTAL	91811.37500	47			

*See Table 124 for Code

TABLE 127. - ATAXIA - SHARPENED ROMBERG - ONE-DAY TESTS

O_1* 47.83**	O_2 38.67	O_3 22.92	O_4 13.00
S_1 62.75	S_2 15.33	S_3 7.92	S_4 36.42
V_1 32.44	V_2 21.25	V_3 38.12	
GRAND MEAN - 30.60416			

* See Table 124 for Code
** **Mean Differences from Pre-Test Baselines**

TABLE 128. - ATAXIA - SOLEC - ANALYSIS OF VARIANCE - ONE-DAY TESTS

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBABILITY
S*	26529.78906	3	8843.26172		
V	663.08325	2	331.54150	.944	---
SV	2106.58325	6	351.09717		
O	1934.54150	3	644.84717	1.193	---
SO	4863.62500	9	540.40259		
VO	3243.83325	6	540.63867	2.120	$< .2$
SVO	4589.48828	18	254.97156		
T	77.04166	1	77.04166	.035	---
ST	6665.78906	3	2221.92969		
VT	900.33325	2	450.16650	5.146	$< .05$
SVT	524.83325	6	87.47220		
OT	832.20825	3	277.40259	1.577	---
SOT	1582.95825	9	175.88425		
VOT	2044.41650	6	340.73608	1.280	---
SVOT	4789.41406	18	266.07837		
TOTAL	61347.92188	95			

* See Table 124 for Codes

TABLE 129. - ATAXIA - SOLEC - ONE-DAY TESTS

O_1* 23.46**	O_2 18.50	O_3 13.08	O_4 12.38
S_1 45.12	S_2 11.88	S_3 2.96	S_4 7.46
T_1† 17.75	T_2 15.96		
V_1 16.88	V_2 20.06	V_3 13.62	
GRAND MEAN 16.85416			

* See Table 124 for Codes
** Mean Differences from Pre-Test Baseline
† T_1 = Rt. Leg, T_2 = Left Leg

TABLE 130. - ATAXIA - WOFEC - ANALYSIS OF VARIANCE - THREE-DAY TEST

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBABILITY
S	239.20000	3	79.73332		
B	2942.59985	4	735.64990	24.535	< .001
SB	359.79980	12	29.98331		
T	0.10000	1	0.10000	.002	--
ST	102.70000	3	34.23332		
BT	87.39990	4	21.84999	1.261	--
SBT	207.79999	12	17.31667		
TOTAL	3939.59912	39			

CODE - FACTORS

S - SUBJECTS 1=A, 2=B, 3=F, 4=G

B - DAYS 1=1st, 2=2nd, 3=3rd, 4=Post Test Early, 5=Post Test Later

T - TESTS 1=WOFEC I, 2=WOFEC II

TABLE 131. - ATAXIA - WOFEC - THREE-DAY TEST

B_1* 19.75**	B_2 3.50	B_3 0.00	B_4 21.00	B_5 15.25
S_1 11.50	S_2 8.10	S_3 13.50	S_4 14.50	
T_1 11.95	T_2 11.58			
GRAND MEAN = 11.90				

* See Table 130 for Code

** Mean Differences from Pre-Test Baselines

TABLE 132. - ATAXIA - WOFEC - NEWMAN-KUELS ANALYSIS
OF "B" FACTOR - THREE-DAY TEST

	B_3	B_2	B_5	B_1	B_4
B_3	--	28	122**	158**	168**
B_2		--	94**	130**	140**
B_5			--	36	46
B_1				--	10
B_4					--

**Significant at the .01 Level

TABLE 133. - ATAXIA - SHARPENED ROMBERG - ANALYSIS OF VARIANCE - THREE-DAY TEST

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBABILITY
S *	6123.19922	3	2041.06641		
B	3013.19595	4	753.29980	1.144	---
SB	7898.79686	12	658.23291		
TOTAL	17035.19531	19			

* See Table 130 for Code

TABLE 134. - ATAXIA - SHARPENED ROMBERG - THREE-DAY TEST

B_1* 28.50**	B_2 0.00	B_3 0.00	B_4 23.50	B_5 22.00
S_1 42.80	S_2 0.00	S_3 0.00	S_4 16.40	
GRAND MEAN = 14.80				

* See Table 130 for Codes
**** Mean Differences from Pre-Test Baselines**

TABLE 135. - ATAXIA - SOLEC - ANALYSIS OF VARIANCE - THREE-DAY TEST

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBABILITY
S *	809.09985	3	269.69995	–	
B	7662.39844	4	1915.59961	5.049	< .025
SB	4552.39844	12	379.36646		
T **	1040.39990	1	1040.39990	29.007	< .025
ST	107.59999	3	35.86665		
BT	1840.59985	4	460.14990	2.399	< .2
SBT	2301.39990	12	191.78333		
TOTAL	18313.88672	39			

* See Table 130 for Codes
** T1=Right Leg; T2=Left Leg

TABLE 136. - ATAXIA - SOLEC - THREE-DAY TEST

B_1* 0.00**	B_2 3.00	B_3 0.00	B_4 33.50	B_5 23.25
S_1 18.00	S_2 11.40	S_3 13.00	S_4 5.40	
T_1 6.85	T_2 17.05			
GRAND MEAN = 11.95				

* See Table 130 for Code
** Mean Differences from Pre-Test Baselines

TABLE 137. - ATAXIA - SOLEC - NEWMAN-KUELS ANALYSIS OF "B" FACTOR - THREE-DAY TEST

	B_1	B_3	B_2	B_5	B_4
B_1	--	0	24	186	268*
B_3		--	24	186	268*
B_2			--	162	244*
B_5				---	82
B_4					--

* Significant at the .05 Level

TABLE 138. - ATAXIA - WOFEC - ANALYSES OF VARIANCE - SEVEN-DAY TEST

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBABILITY
S	79.12500	3	26.37500		
B	1570.75000	7	224.39285	4.424	<.005
SB	1065.12500	21	50.72023		
T	9.00000	1	9.00000	.289	--
ST	93.37500	3	31.12500		
BT	149.75000	7	21.39285	.735	--
SBT	610.87500	21	29.08928		
TOTAL	3578.00000	63			

CODE-FACTORS	LEVELS
S - SUBJECTS	1=A, 2=B, 3=D, 4=G
B - DAYS	1=1st Day Eyes Open (E.O.), 2=2nd Day, E.O., 3=1st Day Eyes Closed (E.C.) 4=2nd Day, E.C., 5=3rd Day, E.C., 6=4th Day E.C., 7=Post Test Immediate, 8=Post Test + 2 Hours
T - TESTS	1=Right Leg, 2=Left Leg

TABLE 139. - ATAXIA - WOFEC - SEVEN-DAY TEST

B_1*	B_2	B_3	B_4	B_5	B_6	B_7	B_8
12.12**	2.62	14.75	11.62	13.62	7.62	20.25	15.38
S_1 13.88		S_2 11.69		S_3 10.88		S_4 12.56	
T_1 12.62		T_2 11.88					
GRAND MEAN 12.25000							

* See Table 138 for Codes
** Mean Difference from Pre-Test Baselines

TABLE 140. - ATAXIA - WOFEC - NEWMAN-KUELS ANALYSIS OF "B" FACTOR - SEVEN-DAY TEST

	B_2	B_6	B_4	B_1	B_5	B_3	B_8	B_7
B_2	--	41	72	76*	88*	97*	102*	141**
B_6		--	32	36	48	57	62	101*
B_4			--	4	16	25	30	69
B_1				--	12	21	26	65
B_5					--	9	14	53
B_3						--	5	44
B_8							--	39
B_7								--

** Significant at the .01 Level
* Significant at the .05 Level

TABLE 141. - ATAXIA - SHARPENED ROMBERG - ANALYSIS OF VARIANCE - SEVEN-DAY TEST

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBABILITY
S *	68429.25000	3	22809.75000		
B	25419.00000	7	3631.28564	1.991	$< .2$
SB	38289.75000	21	1823.32129		
TOTAL	132138.00000	31			

* See Table 138 for Codes

TABLE 142. - ATAXIA - SHARPENED ROMBERG - SEVEN-DAY TEST

B_1*	B_2	B_3	B_4	B_5	B_6	B_7	B_8
67.50**	43.00	79.25	124.00	99.75	89.75	84.25	30.50
S_1 92.50		S_2 15.00		S_3 141.62		S_4 59.88	
GRAND MEAN 77.25000							

* See Table 138 for Codes
** Mean Differences from Pre-Test Baselines

TABLE 143. - ATAXIA - SOLEC - ANALYSIS OF VARIANCE - SEVEN-DAY TEST

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBABILITY
S*	5720.81250	3	1906.93750		
B	26230.93750	7	3747.27661	12.795	<.001
SB	6150.18750	21	292.86597		
T	90.25000	1	90.25000	.044	---
ST	6134.62500	3	2044.87500		
BT	2132.25000	7	304.60693	.664	---
SBT	9631.87500	21	458.66064		
TOTAL	56090.93750	63			

*See Table 138 for Codes

TABLE 144. - ATAXIA - SOLEC - SEVEN-DAY TEST

B_1*	B_2	B_3	B_4	B_5	B_6	B_7	B_8
13.75**	6.62	54.00	68.75	52.12	47.62	55.75	35.12
S_1 52.38		S_2 33.94		S_3 49.75		S_4 30.81	
T_1 40.53		T_2 42.91					
GRAND MEAN 41.71875							

* See Table 136 for Codes
** **Mean Differences from Pre-Test Baselines**

TABLE 145. - ATAXIA - SOLEC - NEWMAN-KUELS ANALYSIS OF "B" FACTOR - SEVEN-DAY TEST

	B_2	B_1	B_8	B_6	B_5	B_3	B_7	B_4
B_2	--	57	228**	329**	364**	379**	393**	497**
B_1		--	171*	271**	307**	322**	336**	440**
B_8			--	100	136	151	165	269**
B_6				--	36	51	65	169
B_5					--	15	29	133
B_3						--	14	118
B_7							--	104
B_4								--

** Significant at the .01 Level
* Significant at the .05 Level

TABLE 146. - WALKING LEVELS ANALYSIS OF VARIANCE - ONE-DAY TESTS

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBABILITY
S	473.40869	3	157.80289		
V	1964.25049	2	982.12524	13.648	< .01
SV	431.77539	6	71.96255		
A	7966.70703	3	2655.56885	55.539	< .001
SA	430.32861	9	47.81429		
VA	780.53320	6	130.08887	4.508	< .01
SVA	519.37524	18	28.85417		
D	25.31764	1	25.31764	.265	---
SD	286.41260	3	95.47086		
VD	39.53127	2	19.76563	.330	---
SVD	359.04736	6	59.84122		
AD	148.66724	3	49.55574	1.402	---
SAD	318.17822	9	35.35313		
VAD	263.03906	6	43.83984	2.009	< .2
SVAD	392.78247	18	21.82124		
TOTAL	14399.33984	95			

CODE - FACTORS

Code	Factor	Levels
S	SUBJECTS	1=A, 2=B, 3=C, 4=D
V	ROTATION RATE	1=3RPM, 2=4RPM, 3=5RPM
A	WALKING ROOM RADIUS	1=20 Ft. 2=40 Ft., 3=60 Ft., 4=70 Ft.
D	DIRECTION OF TRAVEL	1=Pro-Spin, 2=Anti-Spin

TABLE 147. - WALKING LEVELS - ONE-DAY TESTS

A_1* 45.98*	A_2 28.50	A_3 25.45	A_4 22.56
D_1 30.11	D_2 31.14		
S_1 28.04	S_2 32.25	S_3 33.33	S_4 28.87
V_1 36.59	V_2 29.62	V_3 25.65	
GRAND MEAN 30.62184			

* See Table 146 for Codes

** **Mean Scores in Seconds**

TABLE 148. - WALKING - NEWMAN-KUELS ANALYSIS
OF "A" FACTOR - ONE-DAY TESTS

	A_4	A_3	A_2	A_1
A_4	---	69.5	142.6	562**
A_3		---	73.1	492.5**
A_2			---	419.4**
A_1				---

** Significant at the .01 Level
* Sifnificant at the .05 Level

TABLE 149. - WALKING - NEWMAN-KUELS ANALYSIS
OF "V" FACTOR - ONE-DAY TESTS

	V_3	V_2	V_1	
V_3	---	127.1	351.1**	
V_2		---	222*	
V_1			---	

** Significant at the .01 Level
* Significant at the .05 Level

TABLE 150. - CARGO TRANSFER LEVELS ANALYSIS OF VARIANCE - ONE-DAY TESTS

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBABILITY
S *	218.71223	3	72.90407		
V	1370.85400	2	685.42700	8.335	<.025
SV	493.40259	6	82.23376		
A	4986.88281	3	1662.29419	22.784	<.001
SA	656.62744	9	72.95860		
VA	592.55713	6	98.75952	1.608	---
SVA	1105.68408	18	61.42688		
D	209.44983	1	209.44983	18.885	<.025
SD	33.27206	3	11.09069		
VD	4.96645	2	2.48323	.078	---
SVD	190.36539	6	31.72755		
AD	324.03662	3	108.01221	4.116	<.05
SAD	236.16284	9	26.24031		
VAD	141.10559	6	23.51759	.816	---
SVAD	518.58203	18	28.81010		
TOTAL	11082.64453	95			

* See Table 146 for Codes

TABLE 151. - CARGO TRANSFER LEVELS - ONE-DAY TESTS

A_1* 40.88**	A_2 29.69	A_3 25.10	A_4 21.82
D_1 27.90	D_2 30.85		
S_1 27.34	S_2 29.45	S_3 31.59	S_4 29.10
V_1 34.49	V_2 28.15	V_3 25.48	
GRAND MEAN 29.37289			

* See Table 146 for Codes
** **Mean Scores in Seconds**

TABLE 152. - CARGO TRANSFER LEVELS - NEWMAN-KUELS ANALYSIS OF "V" FACTOR - ONE-DAY TESTS

	V_3	V_2	V_1
V_3	---	85.3	288.3*
V_2		---	203.*
V_1			---

** Significant at the .01 Level
* Significant at the .05 Level

TABLE 153. - CARGO TRANSFER LEVELS - NEWMAN-KUELS ANALYSIS OF "A" FACTOR - ONE-DAY TESTS

	A_4	A_3	A_2	A_1
A_4	---	78.7	188.9	457.5**
A_3		---	110.2	378.7**
A_2			---	268.5*
A_1				---

** Significant at the .01 Level
* Significant at the .05 Level

TABLE 154. - CARGO PICKUP LEVELS ANALYSIS OF VARIANCE - ONE-DAY TESTS

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBABILITY
S*	329.43066	3	109.81021		
V	228.24631	2	114.12315	2.203	<.2
SV	310.85815	6	51.80969		
A	1770.98193	3	590.32715	12.036	<.005
SA	441.43311	9	49.04811		
VA	43.10789	6	7.18465	.095	---
SVA	1360.55566	18	75.58643		
D	217.50259	1	217.50259	8.817	<.1
SD	74.00601	3	24.66867		
VD	18.81104	2	9.40552	.554	---
SVD	101.93388	6	16.98897		
AD	9.93858	3	3.31286	.065	---
SAD	458.21216	9	50.91246		
VAD	60.93668	6	10.15611	.704	---
SVAD	259.67798	18	14.42655		
TOTAL	5685.61719	95			

* See Table 146 for Codes

TABLE 155. - CARGO PICKUP LEVELS - ONE-DAY TESTS

A_1* 31.65**	A_2 21.40	A_3 21.74	A_4 22.12
D_1 22.72	D_2 25.73		
S_1 22.60	S_2 27.11	S_3 24.59	S_4 22.61
V_1 25.12	V_2 25.51	V_3 22.06	
GRAND MEAN = 24.22810			

* See Table 146 for Codes
** Mean Scores in Seconds

TABLE 156. - CARGO PICKUP - NEWMAN-KUELS ANALYSIS OF "A" FACTOR - ONE-DAY TESTS

	A_2	A_3	A_4	A_1
A_2	---	8.3	17.4	246.2*
A_3		---	9.1	237.9*
A_4			---	228.8*
A_1				---

** Significant at the .01 Level

TABLE 157. - CARGO HANDLING ANALYSIS OF VARIANCE - ONE-DAY TESTS

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBABILITY
S *	788.63403	3	262.87793		
V	748.14868	2	374.07422	6.819	<.05
SV	329.13306	6	54.85551		
A	375.75122	3	125.25374	1.480	---
SA	761.56129	9	84.61792		
VA	1824.59888	6	304.09961	3.422	<.025
SVA	1599.61941	18	88.86768		
TOTAL	6427.45313	47			

* See Table 146 for Codes

TABLE 158. - CARGO HANDLING - ONE-DAY TESTS

A_1* 65.13**	A_2 66.71	A_3 60.78	A_4 68.28
S_1 71.01	S_2 64.76	S_3 65.57	S_4 59.58
V_1 69.67	V_2 65.92	V_3 60.08	
GRAND MEAN 65.22289			

*See Table 146 for Codes
** **Mean Scores**

TABLE 159. - CARGO HANDLING - NEWMAN-KUELS ANALYSIS OF "V" FACTOR - ONE-DAY TESTS

	V_3	V_2	V_1	
V_3	--	93.6	153.5*	
V_2		---	59.9	
V_1			---	

** Significant at the .01 Level
* Significant at the .05 Level

TABLE 160. - LADDER CLIMBING ANALYSIS OF VARIANCE - ONE-DAY TESTS

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBABILITY
S	843.44019	3	281.14673		
V	104.67909	2	52.33954	.654	---
SV	479.97534	6	79.99588		
D	6.80005	1	6.80005	.109	---
SD	186.62476	3	62.20825		
VD	58.57806	2	29.28903	2.583	<.2
SVD	68.03516	6	11.33919		
A	7.39823	1	7.39823	.032	---
SA	702.35889	3	234.11963		
VA	189.14214	2	94.57106	11.564	<.01
SVA	49.06900	6	8.17817		
DA	9.15762	1	9.15762	2.038	---
SDA	13.47732	3	4.49244		
VDA	8.94856	2	4.47428	.463	---
SVDA	57.98166	6	9.66361		
R	284.79932	1	284.79932	10.274	<.05
SR	83.16092	3	27.72031		
VR	2770.66309	2	1385.33154	28.089	<.001
SVR	295.91943	6	49.31990		
DR	42.86707	1	42.86707	20.146	<.025
SDR	6.38338	3	2.12779		
VDR	16.68402	2	8.34201	.827	---
SVDR	65.90342	6	10.98390		
AR	20.39670	1	20.39670	5.877	<.1
SAR	10.41132	3	3.47044		
VAR	28.88916	2	14.44458	4.036	<.1

CODE - FACTORS	LEVELS
S - SUBJECTS	1=A, 2=B, 3=C, 4=D
V - ROTATION RATE	1=3 RPM, 2=4 RPM, 3=5 RPM
D - DIRECTION OF ORIENTATION	1=Pro-Spin, 2=Anti-Spin
A - DIRECTION OF TRAVEL	1=Descent, 2=Ascend
R - REPLICATIONS	1=1st, 2=2nd

TABLE 160. - LADDER CLIMBING ANALYSIS OF VARIANCE - ONE-DAY TESTS - continued

SVAP	21.47183	6	3.57864		
DAP	3.31893	1	3.31893	.327	---
SDAP	30.43576	3	10.14525		
VDAP	3.45135	2	1.72567	.237	---
SVDAP	43.74492	6	7.29082		
TOTAL	6508.73438	95			

TABLE 161. - LADDER - ONE-DAY TESTS

A_1* 41.20**	A_2 40.64		
B_1 39.20	R_2 42.64		
D_1 40.65	D_2 41.19		
S_1 38.08	S_2 40.30	S_3 45.87	S_4 39.43
V_1 39.73	V_2 42.27	V_3 40.76	
GRAND MEAN = 40.91924			

* See Table 160 for Codes

** Mean Time in Seconds

TABLE 162. - WALKING ANALYSIS OF VARIANCE - THREE-DAY TEST

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBABILITY
S	78.67242	3	26.22414		
B	39.06255	1	39.06255	74.521	<.005
SB	1.57253	3	0.52418		
D	16.81004	1	16.81004	3.032	<.2
SD	16.63496	3	5.54499		
BD	10.89005	1	10.89005	.635	---
SBD	51.47495	3	17.15831		
TOTAL	215.11749	15			

CODE - FACTORS	LEVELS
S - SUBJECTS	1=A, 2=B, 3=F, 4=G
B - TEST DAYS	1=DAY 2, 2=DAY 3
D - DIRECTION OF TRAVEL	1=Pro-Spin, 2=Anti-Spin

TABLE 163. - WALKING - THREE-DAY TEST

B_1* 28.35**	B_2 25.22		
D_1 25.76	D_2 27.81		
S_1 29.28	S_2 23.22	S_3 27.00	S_4 27.65
GRAND MEAN = 26.78749			

* See Table 162 for Scores

** Mean Scores in Seconds

TABLE 164. - WALKING ANALYSIS OF VARIANCE - SEVEN-DAY TEST

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBABILITY
S	698.18973	3	232.72989		
B	209.67197	5	41.93439	1.700	<.2
SB	370.00562	15	24.66704		
D	27.99764	1	27.99764	5.791	<.1
SD	14.45750	3	4.81917		
BD	18.87996	5	3.77599	.7469	--
SBD	75.82451	15	5.05497		
TOTAL	1414.93629	47			

CODE - FACTORS — **LEVELS**

S - SUBJECTS — **1=A, 2=B, 3=D, 4=G**

B - TEST DAYS — **1=Day 1, 2=Day 3, 3=Day 4, 4=Day 5, 5=Day 6, 6=Day 7**

D - DIRECTION OF TRAVEL — **1=Pro-Spin, 2=Anti-Spin**

TABLE 165. - WALKING - SEVEN-DAY TEST

B_1* 26.92	B_2 21.46	B_3 23.80	B_4 21.18	B_5 21.86	B_6 25.00
D_1 22.61**	D_2 24.13				
S_1 23.80	S_2 19.02	S_3 29.29	S_4 21.38		
GRAND MEAN = 23.37080					

* See Table 160 for Codes
** **Mean Scores in Seconds**

TABLE 166. - CARGO TRANSFER ANALYSIS OF VARIANCE - THREE-DAY TEST

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBABILITY
S*	200.49237	3	66.83078		
B	75.69000	1	75.69000	2.321	---
SB	97.83481	3	32.61160		
D	7.29007	1	7.29007	1.271	---
SD	17.20497	3	5.73499		
BD	3.42251	1	3.42251	.118	---
SBD	87.16237	3	29.05412		
TOTAL	489.09668	15			

* See Table 162 for Codes

TABLE 167. - CARGO TRANSFER - THREE-DAY TEST

B_1* 29.16**	B_2 24.81		
D_1 26.31	D_2 27.66		
S_1 27.98	S_2 21.82	S_3 26.45	S_4 31.70
GRAND MEAN = 26.98749			

* See Table 162 for Codes
** **Mean Scores in Seconds**

TABLE 168. - CARGO TRANSFER ANALYSIS OF VARIANCE - SEVEN-DAY TEST

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBABILITY
S *	979.61549	3	326.53823		
B	72.08846	5	14.41769	.724	---
SB	298.47827	15	19.89854		
D	92.12947	1	92.12947	17.526	< .025
SD	15.77061	3	5.25687		
BD	9.12358	5	1.82472	.317	---
SBD	86.31007	15	5.75400		
TOTAL	1553.51563	47			

* See Table 164 for Codes

TABLE 169. - CARGO TRANSFER - SEVEN-DAY TEST

B_1* 25.78	B_2 22.50	B_3 22.91	B_4 22.51	B_5 22.34	B_6 24.05
D_1** 21.96	D_2 24.73				
S_1 23.43	S_2 17.97	S_3 30.39	S_4 21.60		
GRAND MEAN = 23.34789					

* See Table 164 for Codes
** **Mean Scores in Seconds**

TABLE 170. - CARGO PICKUP ANALYSIS OF VARIANCE - THREE-DAY TEST

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBABILITY
S*	316.41479	3	105.47159		
B	1.44000	1	1.44000	.090	---
SB	47.88486	3	15.96162		
D	92.16011	1	92.16011	6.100	<.1
SD	45.32492	3	15.10831		
BD	12.25002	1	12.25002	12.394	<.05
SBD	2.96501	3	0.98834		
TOTAL	518.43896	15			

* See Table 162 for Codes

TABLE 171. - CARGO PICKUP - THREE-DAY TEST

B_1* 24.20**	B_2 23.60		
D_1 21.50	D_2 26.30		
S_1 22.8	S_2 22.18	S_3 31.15	S_4 23.18
GRAND MEAN = 23.89999			

* See Table 162 for Codes
** Mean Scores in Seconds

TABLE 172. - CARGO PICKUP ANALYSIS OF VARIANCE - SEVEN-DAY TEST

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBABILITY
S *	752.85352	3	250.95117		
B	80.71852	5	16.14369	.893	---
SB	271.05640	15	18.07042		
D	165.39038	1	165.39038	24.050	< .025
SD	20.63062	3	6.87687		
BD	10.78685	5	2.15737	1.245	---
SBD	25.99553	15	1.73304		
TOTAL	1327.4314[illegible]	47			

* See Table 164 for Codes

TABLE 173. - CARGO PICKUP - SEVEN-DAY TEST

B_1* 22.78	B_2 19.69	B_3 22.21	B_4 19.31	B_5 19.95	B_6 20.62
D_1 18.90**	D_2 22.62				
S_1 16.78	S_2 22.13	S_3 26.62	S_4 17.51		
GRAND MEAN = 20.76038					

* See Table 164 for Codes
** **Mean Scores in Seconds**

TABLE 174. - CARGO HANDLING ANALYSIS OF VARIANCE - THREE-DAY TEST

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBABILITY
S *	2219.42383	3	739.80766		
B	323.84985	1	323.84985	3.121	<.2
SB	235.74396	3	78.58131		
TOTAL	2779.01758	7			

* See Table 162 for Codes

TABLE 175. - CARGO HANDLING - THREE-DAY TEST

B_1* 78.00**	B_2 65.28		
S_1 69.85	S_2 50.45	S_3 67.50	S_4 97.75
GRAND MEAN 71.63745			

* See Table 162 for Code
** **Mean Scores in Seconds**

TABLE 176. - CARGO HANDLING ANALYSIS OF VARIANCE - SEVEN-DAY TEST

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBABILITY
S *	993.79224	3	331.26392		
B	404.60840	5	80.92168	1.575	---
SB	770.53931	15	51.36928		
TOTAL	2168.93994	23			

* See Table 164 for Code

TABLE 177. - CARGO HANDLING - SEVEN-DAY TEST

B_1* 60.12	B_2 53.02	B_3 51.48	B_4 52.52	B_5 62.52	B_6 56.40
S_1 63.62**	S_2 53.23	S_3 46.95	S_4 60.25		
GRAND MEAN 56.01247					

* See Table 164 for Codes
** Mean Scores in Seconds

TABLE 178. - FORCE PULL ANALYSIS OF VARIANCE - THREE-DAY TEST

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBABILITY
S *	1171.84375	3	390.61458		
T	8288.28125	1	8288.28125	13.285	< .05
ST	1871.59375	3	623.86458		
B	472.78125	1	472.78125	6.865	< .1
SB	206.59375	3	68.86458		
TB	16.53125	1	16.53125	1.171	---
STB	42.34375	3	14.11458		
D	166.53125	1	166.53125	4.239	< .2
SD	117.84375	3	39.28125		
TD	101.53125	1	101.53125	2.711	< .2
STD	112.34375	3	37.44791		
BD	26.28125	1	26.28125	.435	---
SBD	181.09375	3	60.36458		
TBD	57.78125	1	57.78125	2.220	---
STBD	78.09375	3	26.03125		
TOTAL	12911.46875	31			

* See Table 162 for Codes - "D" = Orientation Direction

TABLE 179. - FORCE PULL - THREE-DAY TEST

B_1* 63.06**	B_2 55.38		
D_1 61.50	D_2 56.94		
S_1 54.88	S_2 69.62	S_3 55.50	S_4 56.88
T_1 43.12	T_2 75.32		
GRAND MEAN = 59.21875			

* See Table 150 and 151 for Codes

** **Mean Force in pounds**

TABLE 180. - FORCE PULL ANALYSIS OF VARIANCE - SEVEN-DAY TEST

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBABILITY
S *	6312.53125	3	2104.17700		
T	29225.25781	1	29225.25781	45.652	< .01
ST	1920.53125	3	640.17708		
B	219.21875	5	43.84375	.866	---
SB	758.90625	15	50.59375		
TB	267.55200	5	53.51039	1.496	---
STB	536.40625	15	35.76041		
D	536.76025	1	536.76025	19.316	<.025
SD	83.36458	3	27.78819		
TD	822.51025	1	822.51025	652.568	<.001
STD	3.78125	3	1.26042		
BD	75.30208	5	15.06042	.692	---
SBD	326.32275	15	21.75484		
TBD	198.55208	5	39.71040	1.795	<.2
STBD	331.90625	15	22.12708		
TOTAL	41618.89063	95			

See Table 164 for Codes T_1 = Overhead T_2 = Forward

TABLE 181. - FORCE PULL - SEVEN-DAY TEST

B_1 * 49.44**	B_2 50.50	B_3 52.56	B_4 53.51	B_5 53.06	B_6 53.31
D_1 54.40	D_2 49.67				
S_1 57.96	S_2 61.96	S_3 42.75	S_4 45.46		
T_1 34.58	T_2 69.48				
GRAND MEAN 52.03125					

* See Tables 164 and 180 for Codes
** Mean Force in Pounds

SECTION IV
DISCUSSION AND CONCLUSIONS

This initial test program was designed to survey a large number of parameters in an effort to develop reliable criteria for space vehicle design requirements and to establish the most fruitful field for further research. In this respect, the program was highly successful. A large number of development areas were observed that will require extensive work to determine the ultimate or potential impact on rotating vehicles designed to provide artificial gravity. While this study was not designed to answer the question of whether artificial is more desirable than zero gravity, or vice versa, the ability of the test crews to function with a high degree of proficiency and demonstrate good morale and cooperation, without motion sickness, was a pleasant surprise. Because of the great concern for this particular phenomenon, which is well documented in the literature, great caution was exercised in both subject selection and task design. The lack of frank motion sickness in the early tests resulted in the addition of the 45-degree out-of-plane orientations at the work stations on the beam and the addition of head movements to the various tests during the long-duration tests. A surprising, but pleasant, observation by the test subjects was that the head movements, rather than clouding perception and performance, actually "cleared their heads and made the task easier."

These subjective observations were, in part, borne out by the objective data collected. However, the outstanding performance of the test subjects in this study should not be confused with the general population or any other special group. These subjects were carefully selected to be resistant to motion sickness, with only subject C being above average in susceptibility and subject D being classified as average. The remaining subjects were below average in susceptibility and tolerated the rotational environment very well. Further, partially as a safety requirement and partially for test subject comfort, the couches in the 30- and 78-foot work stations were somewhat confining. This reduced the stimuli from the proprioceptor system and may have reduced the overall subjective response to the stimuli of rotational environment. While the major symptoms elicited by rotation are related directly to disturbances of the vestibular system, there is a significant contribution from the proprioceptor network. This was demonstrated most strikingly by subject C. He would lose all stomach awareness, even at 5 rpm, when strapped into either of the work stations. In addition, during periods of inactivity, when stomach awareness tends to be greatest, the distress was ameliorated by his lying on the floor.

Problems associated with eating, sleeping, etc., which had been predicted for the rotational environment, did not occur. These observations are contrary to results of two previous tests conducted as an in-house study on the RTF, which have not been published elsewhere. In both of these tests, the test subjects became severely ill, resulting in an abort after approximately 27 hours in the first study, in which college students were used as test subjects. In the second study, three of four engineers were severely ill for the first three days of a scheduled five-day study. Therefore, recognizing that the subjects used in the study were (1) engineers, (2) highly motivated, (3) in good physical condition, and (4) mixed with respect to susceptibility to motion sickness, the results of this study are valid. The ultimate significance of the data requires that additional evaluations be conducted with a wider variety of test subjects and more highly controlled test conditions.

Biomedical Considerations

Normal patterns of physiological response to graded activity were obtained throughout the experimental program. The work related to moving radially along the beam of the RTF in ladder climbing and station changes, plus tangential locomotion and cargo handling suggested that high levels of energy expenditure might be required. It was anticipated that fatigue and dehydration might influence performance and degrade the validity of task accomplishment. Ladder climbing and the walking room regimen did require moderate physical activity, and subjective comments relative to fatigue were generally correlatable with the rotational velocity. Biochemical and physiological data reflected that although physical stress was incurred during task activity on the facility, the stress did not result in measurable fatigue. Fluid changes, because of environmental warmth or strenuous activity, were not sufficient to affect motor activity. While use of heart rate as an absolute indicator of physical work is questionable, it does indicate certain trends with respect to cardiac cost and may be used in a liberal way to compare task-to-task or day-to-day effort with regard to a given individual or group of individuals. EKG monitoring was used in this program as a safety requirement to insure test subject well being, as well as indicate the test subject activity level.

The majority of the analysis was performed on data obtained in the one-day tests since sufficient data were available to permit averaging and comparison of the test subjects during this period. Values obtained during the three- and seven-day tests were comparable for given tasks but were of insufficient quantity to permit individual evaluations. The force vectors generated within the rotational environment produced visual illusions and increased work, as was expected. The increase in total g loading was even observed in the passive radial transfer (elevator) wherein heart rate was greater during travel from the hub to the periphery than was observed in the reverse direction.

No significant trends in either heart rate or blood pressure were noted during the three- and seven-day tests. Further, there was no increase in orthostatic tolerance or work capacity, as had been expected, in response to the greater loading in the increased g forces. A finding of special interest was the change in horizontal visual phoria, progressing from exophoria in the early stages of the seven-day test to esophoria during the middle phase and developing a mixed phoric response among the test subjects at the end of the test period. This suggests a changing nystagmic influence during adaptation that could affect display monitoring in a rotating station. No changes were observed in either the visual acuity or accommodation tests, which tends to minimize the significance of the changing phoria upon task activity. However, further investigation of the visual changes is desirable to assess the potential impact upon visual performance in the rotational environment.

Habitability per se was adequate for the seven-day period as evaluated by personnel attitudes, sleep patterns, and food consumption. Privacy was compromised in the bunk area, but no problems were noted among personnel within any of the three groups. The test subjects routinely retired around 9:30 p.m. and arose between 6 and 6:30, with little or no activity noted in the interim. Personal hygiene was maintained by frequent use of the shower and lavatory. Personal hygiene and meal preparation usually occupied about an hour and 30 minutes each morning. Galley provisions for a longer-duration test should provide a reasonably large oven and several electric burners. Since fresh foods can be provided periodically while the beam is in rotation, preparation of meals need not be limited.

An illusion of an inclined floor is produced in the rotating vehicle, which is related to the difference in radius at the periphery of the room and that on the center line. This incline is sufficient to produce a head-down illusion if the bunks are oriented with the head toward the outside when the body is oriented longitudinally with the direction of rotation. Even when the radial discrepancy was corrected with slant boards, the illusion prevailed when a test subject slept with his head outboard. This phenomena may simply be a carry-over from the visual illusion of the floor inclination. This problem may be corrected by arranging the bunks with the head toward the center line of the vehicle or the long axis aligned in the axial direction.

More recreational pursuits would be desirable. There was some tendency for personnel to select a limited recreational activity or a television program that was of little or no interest to the other test subjects. Additional areas for recreation would need to be integrated with the experimental goals and test objectives. The elucidation of certain problems found in this study with respect to test area responses to the rotating environment requires further study.

Short-Term Memory Evaluations

Many of the naive individuals exposed to the rotational environment had expressed such observations as "it feels like I have just had a strong drink," "I'm having trouble thinking," "my tongue is all twisted," etc. Also, it was observed that the use of directional arrows to reschedule an event produced confusion in some crew members. On one occasion, the Stromberg dexterity device had been opened 180 degrees in the wrong direction, requiring the movement of blocks to the left rather than to the right, which resulted in a doubling of performance time. It required several trials and the logic of two test subjects to discover the problem. An effort was made to elucidate the extent of short-term memory loss by adding the mental arithmetic and memory drum tasks to the three- and seven-day tasks. These tasks failed to demonstrate a loss of cognitive capability in the rotating environment. Several observations are pertinent in this regard. First, there was considerable difference between test subjects. Two of the test subjects performed nearly perfectly at all times, both in and out of the rotating environment. The other two obtained approximately 90-percent correct answers during pre-test evaluations. These latter two test subjects were most affected by rotation, particularly during the first two days. Their scores were reduced dramatically after five and ten head movements during the first two days of the seven-day test. The perfect performers did not respond to the rotational environment. For the entire test, the scores were significantly reduced in the 90-percent subjects, with the greatest reduction being in response to five head movements. These observations, and discussions with the test subjects resulted in the conclusion that differences among test subjects must be taken into account in designing such tests for future evaluations. The version used in this test series did not tax some test subjects to perform to their full capabilities and thus minimized the opportunity to observe any decrement resulting from the rotational test conditions. Because of the limited data, no definite conclusions may be expressed relative to the statistical validity of a mental degradation, but the data are sufficiently strong to make this an area for profitable investigation.

Psychomotor Tests

Sufficient data were obtained to warrant the scheduling of additional research in the psychomotor task area. Again, it is felt that the high motivation of the test subjects used in this test program, coupled with the high degree of both practical and specific training and the relatively high resistance to motion sickness, may have reduced the magnitude of differences in the various tests in response to the selected variables. In the several tests with the DRT, many variables were evaluated several times. However, the statistical significance of the results varied as summarized:

Rotation rate	-	No differences between rates
Time of day	-	AM, faster performance time with more errors
Orientation	-	Anti-spin, slowest performance time with more errors; a tendency for performance time to increase from the pro-spin orientation, rotated stepwise through anti-spin
Stations	-	Preponderance of results indicates that performance is fastest in the following order: hub, 30-foot and 78-foot stations, with more errors being committed at the 78-foot station
Blocks of test days, days and replications	-	Performance improves over test days and/or replications; the first performances are often worse than pre-test baselines; adaptation or recovery to pre-test performances occurs within two days; and learning and/or adaptation occurs throughout the seven-day period.

Other conclusions based on objective test results are that the head motions generated during the performance of the AD mode may actually improve performance and that evidence of fatigue in the CR mode was not produced over periods of two minutes, interspaced in a period of approximately 30 minutes total evaluation of the several modes.

The test subjects, in the thousands of DRT trials, reported some observations relative to results of the psychomotor task, some contrary and some complimentary to the objective results. Some of the impressions shed light on the possible interpretations of the results. Some may be pertinent to the design of future test programs. Those subjective comments included herein fall into one of the four categories and are considered the more important ones:

1. Several test subjects reported that fatigue was higher and performance felt slower at the pro-spin and 45-degree pro-spin orientations at the stations. The objective performance results were diametrically opposed to the subjective impression.

2. The various sequences of light code patterns were memorized to varying degrees. This resulted in the test subject reacting to a light sequence during the CCC and AD modes as a learned sequence rather than the presented code. This obviously influenced the overall test results. The test subjects recommended that more variation of those sequences be included for future test programs to preclude or at least complicate this capability. A related aspect of the reacting to lights rather than codes in DRT performance was a response that

the test subjects termed "itchy fingers" or anticipation responses. That is, they thought they recognized a sequence and made anticipation responses, which, if they guessed wrong, resulted in increased errors. This reaction may explain the cause of an increase in average errors by the test subjects as they continued in the test program.

3. The test subjects observed, as the test progressed, that certain codes were easier to perform than others. This, coupled with the use of light sequences, influenced the overall performance. Those trials requiring a large number of third and fourth finger actions were slower. Also, successive codes that were similar were more difficult.

4. The DRT task produced many instances of apparent confusion. It was observed by the test personnel with or without awareness by the test subjects or was reported as comment by the test subjects. Evidences of this confusion during performance of the DRT task were related to the conduct of the correct number of trials while at the required orientation. As noted in the section on short-term memory, consistent difficulty was experienced by all test subjects in remembering the number of trials, couch orientation, display sequences, etc. The problem was serious enough to require the addition of counting aids and orientation monitoring to insure adherence to the protocol or to determine the protocol followed after the test. This mental phenomena created much anxiety in both the test subjects and test personnel, until resolution of the problems was obtained, since it was not anticipated during the formulation of the original experimental design.

Locomotion

The one observation that was consistent during test subject debriefings was that walking in the pro-spin direction in the movable enclosure was easiest. In that direction body control and starting and stopping were easy, even at g levels as low as 0.1 g. However, at 40 feet with a rotational rate of 4 rpm, which produces 0.2 g's, body control was found to be acceptable in either direction. It is noteworthy that performance and confidence continued to improve over the seven-day test period. Subjectively, the test subjects felt that it would be desirable to increase the length of the walking floor and provide more realistic cargo packages to increase the fidelity of the simulation. The walking procedures at the 70-foot radius at 5 rpm produced a 0.6-g level, resulting in a very "earth-like" situation with respect to balance and work. The most comfortable conditions, from the subjective viewpoint, were at the

60-foot radius at 4 rpm, which produces an 0.3 gravitational force. All activities at the 20-foot station, even at 5 rpm (0.17 g's), were both uncomfortable and unstable. This was in great part due to the low traction and the relatively large body angle when a subject was at the back side of the room. The effective radius at the back side was 25 feet when the room was positioned at the 20-foot radius. The radial difference made it necessary for the test subject to stand at an approximate 35-degree angle, which completely prevented body control when a subject stooped to pick up a cargo package while he was facing the anti-spin direction. This position compares with the 18- and 30-foot floor levels of the potential Skylab experiment and indicates the need for a curved or sharply angled floor at these short radii.

Radial locomotion, early predicted to be the greatest problem in crew transfer, did not produce any excessively stressful stimuli in the vestibular system. There was no problem in traversing the beam from one end to the other or passing through the axis of rotation. The use of the elevator was reported to be subjectively ideal, without undue stress during transfer from the hub to the periphery of the beam. The requirement for restraint was noted at the short radii because of the greater ratio of the Coriolis to the artificial-gravity forces.

Radial transfer using the ladder yielded some expected and some unexpected results. Although the stride is reduced during tangential locomotion for balance and bodily control, the length of the step was increased during radial transfer in response to the reduced gravity. Ladder rungs of 12-inch spacings were found to be extremely uncomfortable, resulting in excessive banging of shins on the higher rungs. It has been recommended that rung spacing start at about 12 inches or more at 65 feet, increasing to 18 to 20 inches at the 25-foot radius, with possibly an occasional "resting rung" at radii of less than 10 feet. A step height of 24 inches, or double rungs, was not comfortable for any individual in this program. The difference in subjective preferences resulted in the expression of different observations with respect to the best ladder, i.e., facing pro-spin or anti-spin while ascending or descending the ladder. Some individuals liked the feeling of the slight Coriolis forces pressing them into the ladder, while others preferred to be held away from the ladder. The concensus was that a single ladder, facing either direction, would be acceptable on the space station because of the relatively slow rate of translation (i.e., 1.35 feet per second), which produces mild Coriolis forces. The use of a rope for climbing or descending was felt to be unsafe and required excessive work. It was stated that a fireman's pole might be useful in descent from the hub to living quarters. This potential should be evaluated.

Ataxia

It was decided initially that the test subjects would remain in the crew module during shut-down activities because of potential adverse physiological reactions to the cessation of rotation with the resultant safety hazards. When the RFT was completely stopped, the test subjects walked to the hub area, which provided adequate free space for the administration of the test battery. Subsequently it was determined that no physiological or safety problems were produced by the shut-down procedures. However, it was noted that the walk to the hub area hastened the subject's readaptation to non-rotational environment, as did the performance of the test battery. Consequently, for more accurate measurement of the effects of rotation it was decided that in future tests the subjects should be in the test area and remain motionless until required to perform the ataxia tests. This procedure was instituted during the seven-day tests. Because any movement increased test subject readaptation to non-rotation, future tests should consider controlling test subject and test order effects in the mode of test battery administration. A conclusion from these test observations was that the process of readaptation may be hastened by a systematic series of head motions. This conclusion is consistent with the evidence for more rapid adaptation to rotational environment by the systematic use of controlled head motions.

The post-rotation ataxia test results indicated that although there was some recovery during the 25 minutes required for the administration of the test battery, two to four hours of recovery during ground-based activities were required before any of the individuals could consistently perform up to the pre-rotation baselines. However, readaptation continued for at least 24 hours before all symptoms disappeared, as reported by the test subjects, who had been asked to observe their feelings for the subsequent period and to administer the ataxia test battery to themselves at home 24 hours later. All reported that they had easily achieved baseline values within 24 hours. The test subjects were surprised at the lack of severe symptoms after rotation ceased, which in some cases gave a false sense of confidence. In most cases, poor ataxia test performance contradicted the lack of subjective symptoms in the test subjects. It was apparent that tasks requiring reliance on motion cues, such as driving an automobile, should not be attempted for at least four to six hours after adaptation and departure from a rotational environment.

During the three- and seven-day tests, it had been planned to evaluate postural equilibrium adaptation while the test subjects were rotating. The procedure established was to allow the subjects to perform the ataxia test battery with eyes open until they approached pre-test baseline values and then attempt the test battery with eyes closed. During the three-day tests, all tests were performed with eyes open. By the end of the third day two of the subjects were able to make consistently fair scores in this mode. The abort of the test program prevented any further observations during this test. However, two of the test subjects who had participated in the three-day test reached pre-test baseline values with eyes open at the end of two days during the seven-day test, while the remaining two "naive" test subjects required a full three days. After the eyes-closed mode was reached, test performance was again degraded somewhat, mostly because of learning. This learning component was particularly evident in the WOFEC, where, by trial and error, it was discovered that starting the walk at the hub was much easier than the reverse. Also, minimum head movements while walking or correcting balance were essential, as any gross head or body motion led inevitably to failure. Performance with eyes closed remained sporadic and never reached pre-test baseline values during rotation.

It was apparent from experience with the test battery during the various tests that it was a most useful index of adaptation and recovery. However, its use requires careful consideration of conditions in order to maximize the usefulness of the results.

Future Test Studies

Biomedical. - During the testing, a large number of additional studies were suggested by the results, including confirmation of results of the present program by the use of more susceptible, as well as a larger, population of test subjects. The visual aberrations observed with respect to visual phoria should be pursued to determine the effects on overall visual accommodation. Audiometric problems related to communications were observed that seemed to be, in part, related to the so-called confusion syndrome, which was observable, but defied measurement in these tests. This complex audio-visual response requires further evaluation, as does the confusion component.

Locomotion. - A variation in ladder design and the use of a fireman's pole for radial locomotion should be evaluated. Other techniques of transfer such as hand-cranked pulley systems, mechanized rope, etc. should be considered. The elevator should be designed to reduce the amount of body contact in order that a relatively unstable proprioceptor system should be maintained to prevent compromise of the evaluation. The problems of radial cargo transfer should be investigated. The tangential locomotion evaluations require a more realistic floor design, one that is symmetrically distributed either side of the main radial axis for more valid evaluation of locomotion in the pro- and anti-spin directions. The ergometric considerations of cargo handling and crew transfer over flat and curved floors should be investigated.

Cognition. - Because of the continued evidence of reduced mental function during the early phases of adaption, an open-ended mental arithmetic task should be developed to allow for test subject differences and provide a more sensitive measurement tool. The memory drum may be updated to increase its usefulness in this area of investigation.

Psychomotor tests. - The Langley Complex Coordinator should be used as follows:

1. Because of the inconclusive results obtained for rotation rate, continue test to adequately assess this factor.

2. Continue investigations of foot operations primarily in reference to orientations. These investigations should eliminate the effects on the cabin environment, which may have been the major factor in past tests.

3. Prepare experimental designs that adequately separate learning from adaptation. This recommendation is applicable to several experiments.

4. Investigate effect of additional man-equipment orientations coupled with head motions. (This is applicable to other psychomotor tasks also.)

The decision reaction test device requires some modification but is very useful in this environment with the following provisions:

1. Obtain adequate baselines for all stations for comparisons.

2. Concentrate efforts on first four days to evaluate adaptation. (See LCC comment about learning versus adaptation.)

3. Simplify investigations to better assess affects of variables over longer periods of time, e.g., evaluate one orientation only, or one mode, etc.

4. Provide random and balanced exposures to codes and light sequences.

Additional tests should be incorporated into an engineering evaluation program to provide more design information for station/base-type vehicles that employ artificial gravity environments. The designs should aim at improving the comfort and the performance of the flight crew. The data from this test program are strongly suggestive of potential space vehicle optimizations but require further validation before incorporation into final design.

REFERENCES

1. Leonov, A. A., and Lebedev, V. I. Perception of Space and Time in Outer Space. Nauka Press (Moscow) 1968; in NASATT F-545, May 1969.

2. Space Daily, May 28, 1969.

3. Berry, C. A. Preliminary Clinical Report of the Medical Aspects of Apollos VII and VIII. Aerospace Medicine, vol. 40, 1969, pp. 245-254.

4. Christensen, J. M., and Simons, J. C. Human Performance in Space Systems. Lectures in Aerospace Medicine, USAF SAM, February 1970.

5. Faget, M. A., and Olling, E. H. Orbital Space Stations With Artificial Gravity. The Third Symposium on the Role of the Vestibular Organs in Space Exploration. NASA SP-152, 1967, pp. 7-16.

6. Space Station Program Definition - Statement of Work. NASA RFP 10-7192, April 1969.

7. Dean, F. R., Wood, C. D., and Graybiel, A. The Effects of Drugs in Altering Susceptibility to Motion Sickness in Aerobatics and Slow Rotation Room. Aerospace Medicine, vol. 38, 1967, pp. 842-845.

8. Fregly, A. R., and Graybiel, A. Residual Effects of Storm Conditions at Sea Upon the Postural Equilibrium Functioning of Vestibular Normal and Vestibular Defection Human Subjects. NSAM-935. July 1965.

9. Graybiel, A., Kennedy, R. S., Knoblock, E. C., Guedry, F. E., Mertz, W., McLeod, M. E., Colehour, J. R., Miller, E. F., and Fregly, A. R. The Effects of Exposure to a Rotating Environment (10 rpm) on Four Aviators for a Period of Twelve Days. NSAM-923, March 1965.

10. Graybiel, A., Wood, C. D., Miller, E. F., and Cramer, D. B. Diagnostic Criteria for Grading the Severity of Acute Motion Sickness. Aerospace Medicine, vol. 39, 1968, pp. 435-460.

11. Loret, B. J. Optimization of Manned Orbital Satellite Vehicle Design With Respect to Artificial Gravity. ASD-TR-61-668, WPAFB, Ohio, 1961.

12. Stone, R. W., and Piland, W. M. Potential Problems Related to Weightlessness and Artificial Gravity. NASA TN-D-4980, January 1968.

13. McLeod, M. E., and Meek, J. C. A Threshold Caloric Test: Results in Normal Subjects. NSAM-834, 1962.

14. Fitzgerald, G., and Hallpike, C. S. Studies in Human Vestibular Function: 1. Observations on the Directional Preponderance of Caloric Nystagmus Resulting From Cerebral Lesions. Brain, vol. 65, 1942, pp. 115-137.

15. Clark, B. Thresholds for the Perception of Angular Accelerations in Man. Aerospace Medicine, vol. 38, 1967, pp. 443-450.

16. Newsome, B. D., and Brady, J. F. A Comparison of Performance Involving Head Rotations About Y and Z Axes in a Revolving Space Station Simulator. Aerospace Medicine, vol. 37, 1966, pp. 1152-1157.

17. Miller, E. F. Counterrolling of the Human Eyes Produced by Head Tilt With Respect to Gravity. Acta Otolaryng, vol. 54, 1962, pp. 479-501.

18. Fregly, A. R., and Graybiel, A. An Ataxia Test Battery Not Requiring Rails. Aerospace Medicine, vol. 39, 1968, pp. 277-282.

19. Fregly, A. R., and Graybiel, A. Labyrinthine Defects as Shown by Ataxia and Caloric Tests. Acta Otolaryng. vol. 69, 1970, pp. 216-222.

20. Kennedy, R. S., and Graybiel, A. The Dial Test: A Standardized Procedure for the Experimental Production of Canal Sickness Symptomatology in a Rotating Environment. NSAM-930, 1965.

21. Miller, E. F., and Graybiel, A. Motion Sickness Produced by Head Movements as a Function of Rotational Velocity. Aerospace Medicine, vol. 41, 1970, pp. 1180-1184.

22. Lindquist, E. F. Design and Analysis of Experiments in Psychology and Education. Houghton Mifflin (Boston) 1953.

23. Wolfe, J. W., Kennedy, R. S., and Cramer, R. L. Comparison of Effectiveness of Anti-Motion Sickness Drugs Using Recommended and Larger Than Recommended Doses as Tested in the Slow Rotation Room. Aerospace Medicine, vol. 37, 1966, pp. 259-261.

24. Wood, C. D., and Graybiel, A. Evaluation of Sixteen Anti-Motion Sickness Drugs. Aerospace Medicine, vol. 39, 1968, pp. 1341-1344.

25. Hartley, H. O. Analysis of Variance. Mathematical Methods for Digital Computers. (Edited by A. Ralston and H. Wilf.) John Wiley & Sons (New York) 1962.

26. Winer, B. J. Statistical Principles in Experimental Design. McGraw-Hill (New York) 1962.

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BIBLIOGRAPHY

Atkin, A., and Bender, M. B. Ocular Stabilization During Oscillatory Head Movements. Archives Neurol. vol. 19 (1968) pp. 559-566.

Benson, A. J. Effect of Diphenidol and Prochloroperazine on Semicircular Canal Function in Man. Aerospace Medicine, vol. 40, 1969, pp. 589-595.

Berry, C. A. Preliminary Clinical Report of the Medical Aspects of Apollos VII and VIII. Aerospace Medicine, vol. 40, 1969, pp. 245-254.

Christensen, J. M., and Simons, J. C. Human Performance in Space Systems. Lectures in Aerospace Medicine. USAF SAM, February 1970.

Clark, B. Thresholds for the Perception of Angular Accelerations in Man. Aerospace Medicine, vol. 38, 1967, pp. 443-450.

Clark, B., and Graybiel, A. Human Performance During Adaptation to Stress in the Pensacola Slow Rotation Room. Aerospace Medicine, vol. 32, 1961, pp. 93-106.

Clark, B., and Stewart, J. D. Vestibular and Nonvestibular Information in Judgments of Attitude and Coriolis Motion in a Piloted Flight Simulator. Aerospace Medicine, vol. 38, 1967, pp. 936-940.

Collins, M. Statement from Space in the Apollo 11 Mission. July 17, 1969.

Collins, W. E. "Vestibular Responses From Figure Skaters." Aerospace Medicine, vol. 37, 1966, pp. 1098-1104.

Collins, W. E. "Coriolis Vestibular Stimulation and Visual Surrounds. Aerospace Medicine, 1966, pp. 125-129.

Collins, W. E. Adaptation to Vestibular Disorientation. X. Modification of Vestibular Nystagmus and Vertigo by Means of Visual Stimulation. FAA CAMI AM68-28, October 1968.

Deane, F. R., Wood, C. D., and Graybiel, A. The Effects of Drugs in Altering Susceptibility to Motion Sickness in Aerobatics and the Slow Rotation Room. Aerospace Medicine, vol. 38, 1967, pp. 842-845.

Dowd, P. J., and Cramer, R. L. Habitation Transference in Coriolis Acceleration. Aerospace Medicine, vol. 38, 1967, pp. 1103-1107.

Faget, M. A., and Olling, E. H. Orbital Space Stations With Artificial Gravity. The Third Symposium on the Role of the Vestibular Organs in Space Exploration. NASA SP-152, 1967, pp. 7-16.

Fitzgerald, G., and Hallpike, C. S. Studies in Human Vestibular Function: 1. Observations on the Directional Preponderance of Caloric Nystagmus Resulting From Cerebral Lesions. Brain, vol. 65, 1942, pp. 115-137.

Fregly, A. R., and Graybiel, A. Residual Effects of Storm Conditions at Sea Upon the Postural Equilibrium Functioning of Vestibular Normal and Vestibular Defective Human Subjects. NSAM-935, July 1965.

Fregly, A. R., Graybiel, A., Oberman, A., and Mitchell, R. E. Thousand Aviator Study: Non-Vestibular Contributions to Postural Equilibrium Functions. Aerospace Medicine, vol. 39, 1968, pp. 33-37.

Fregly, A. R., Graybiel, A. An Ataxia Test Battery Not Requiring Rails. Aerospace Medicine, vol. 39, 1968, pp. 277-282.

Fregly, A. R., Graybiel, A. Labyrinthine Defects as Shown by Ataxia and Caloric Tests. Acta Otolaryng, vol. 69, 1970, pp. 216-222.

Graybiel, A., Kennedy, R. S., Knoblock, E. C., Guedry, F. E., Mertz, W., McLeod, M. E., Colehour, J. R., Miller, E. F., and Fregly, A. R. The Effects of Exposure to a Rotating Environment (10 rpm) on Four Aviators for a Period of Twelve Days. NSAM-923, March. 1965.

Graybiel, A., and Fregly, A. R. A New Quantitative Ataxia Test Battery. NSAM-919, March 1965.

Graybiel, A., Miller, E. F., Billingham, J., Waite, R., Berry, C. A., and Dietlein, L. F. Vestibular Experiments in Gemini Flights V and VII. Aerospace Medicine, vol. 38, 1967, pp. 360-370.

Graybiel, A., and Kellogg, R. S. Inversion Illusion in Parabolic Flight: Its Probable Dependence on Otolith Function. Aerospace Medicine, vol. 38, 1967, pp. 1099-1102.

Graybiel, A., Wood, C. D., Miller, E. F., and Cramer, D. B. Diagnostic Criteria for Grading the Severity of Acute Motion Sickness. Aerospace Medicine, vol. 39, 1968, pp. 453-460.

Graybiel, A. Structural Elements in the Concept of Motion Sickness. Aerospace Medicine, vol. 40, 1969, pp. 351-367.

Graybiel, A., and Wood, C.D. Rapid Vestibular Adaptation in a Rotating Environment by Means of Controlled Head Movements, vol. 40, 1969, pp. 638-643.

Graybiel, A. Susceptibility to Acute Motion Sickness in Blind Persons. Aerospace Medicine, vol. 41, 1970, pp. 650-653.

Grose, V.L. Deleterious Effects on Astronaut Capability of Vestibulo-ocular Disturbance During Spacecraft Roll Acceleration. Aerospace Medicine, vol. 38, 1967, pp. 1139-1144.

Guedry, F.E., and Graybiel, A. Rotation Devices Other Than Centrifuges and Motion Simulators. NAS-NRC 902, 1961.

Guedry, F.E., and Crocker, J. Vestibular System in Bioastronautics Data Book. NAS SP-3006, 1964, Section 19, pp. 363-381.

Guedry, F.E. Relations of Vestibular Nystagmus and Visual Performance. Aerospace Medicine, vol. 39, 1968, pp. 570-578.

Hartley, H.O. Analysis of Variance. Mathematical Methods for Digital Computers (Edited by A. Ralston and H. Wilf.) John Wiley & Sons (New York) 1962.

Holmen, R.E., and Runge, F.C. Operational Concepts for a 10-Year Space Station. AAS Paper 70-031. Anaheim, June 1970.

Jones, G.M. Origin Significance and Amelioration of Coriolis Illusions from the Semicircular Canals: A Non-Mathematical Apprisal. Aerospace Medicine, vol. 41, 1970, pp. 483-490.

Kesselman, R.H. Gravitational Effects on Blood Distribution. Aerospace Medicine, vol. 39, 1968, pp. 162-165.

Kennedy, R.S., and Graybiel, A. The Dial Test: A Standardized Procedure for the Experimental Production of Canal Sickness Symptomatology in a Rotating Environment. NSAM-930, 1965.

Leonov, A.A., and Lebedev, V.I. Perception of Space and Time in Outer Space. Nauka Press (Moscow) 1968, in NASATT F-545, May 1969.

Lindquist, E. F. Design and Analysis of Experiments in Psychology and Education. Houghton Mifflin (Boston) 1953.

Lord, D. R., Lohman, R. L., and Lovelett, R. F. An Overview of NASA's Space Station Program. AAS Paper 70-020, Anaheim, June 1970.

Loret, B. J. Optimization of Manned Orbital Satellite Vehicle Design With Respect to Artificial Gravity. ASD-TR-61-668, WPAFB, Ohio, 1961.

McLeod, M. E., and Meek, J. C. A Threshold Caloric Test: Results in Normal Subjects. NSAM-834, 1962.

Middleton, W. C., and White, W. J. Centrifuge Radius Effects on Performance of Entry Tasks. Aerospace Medicine, vol. 39, 1968, pp. 845-848.

Miller, E. F. Counterrolling of the Human Eyes Produced by Head Tilt With Respect to Gravity. Acta Otolaryng, vol. 54, 1962, pp. 479-501.

Miller, E. F., and Graybiel, A. Motion Sickness Produced by Head Movements as a Function of Rotational Velocity. Aerospace Medicine, vol. 41, 1970, pp. 1180-1184.

Miller, E. F., and Graybiel, A. In Preparation, 1971.

Newsom, B. D., and Brady, J. F. A Comparison of Performance Involving Head Rotations About Y and Z Axes in a Revolving Space Station Simulator. Aerospace Medicine, 1966, pp. 1152-1157.

Newsom, B. D., Brady, J. F., and O'Laughlin, T. W. Optokinetic Reflex Responses to Cross-Coupled Gyroscopic Stimuli. Aerospace Medicine, vol. 40, 1969, pp. 509-517.

Newsom, B. D., O'Laughlin, T. W., and Brady, J. F. Reach Effectiveness in a Rotating Environment. Aerospace Medicine, vol. 39, 1968, pp. 505-507.

Reason, J. T., and Graybiel, A. Changes in Selective Estimates of Well-Being During the Onset and Remission of Motion Sickness Sympotomatology in the Slow Rotation Room. Aerospace Medicine, vol. 41, pp. 166-171.

Ryback, R. S. Effects of Alcohol on Memory and its Implication for Flying Safety. Aerospace Medicine, vol. 41, pp. 1193-1195.

Siegel, S. Nonparametric Statistics for the Behavioral Sciences. McGraw-Hill (New York) 1956.

Sinha, R. Coriolis Reaction Effect on Respiration and Blood Flow. Aerospace Medicine, vol. 39, pp. 837-844.

Space Station Program Definition - Statement of Work. NASA RFP 10-7192, April 1969.

Space Daily, May 28, 1969.

Steele, J. E. Motion Sickness and Spacial Perception. Symposium on Motion Sickness With Special Reference to Weightlessness. AMRL TR 63-25.

Stone, R. W., and Piland, W. M. Potential Problems Related to Weightlessness and Artificial Gravity. NASATN-D-4980, January, 1968.

Strickland, Z. Soyuz 9 Medical Reports Puzzling. Aviation Week and Space Tech, November 1970, pp. 51-53.

Thach, J. S., and Graybiel, A. Behavioral Responses of Unrestrained Normal and Labyrinthectomized Squirrel Monkeys to Repeated Zero-Gravity Parabolic Flights. Aerospace Medicine, vol. 39, 1968, pp. 734-738.

Toerge, F., and O'Donnel, C. A. Habitability - A Space Station Form in Relationship to Man. AAS Paper 70-032, Anaheim, June 1970.

Winer, B. J. Statistical Principles in Experimental Design. McGraw-Hill (New York) 1962.

Wolfe, J. W., and Cramer, R. L. Illusions of Pitch Induced by Centripetal Acceleration. Aerospace Medicine, vol. 41, 1970, pp. 1136-1139.

Wolfe, J. W., Kennedy, R. S., and Cramer, R. L. Comparison of Effectiveness of Anti-Motion Sickness Drugs Using Recommended and Larger than Recommended Doses as Tested in the Slow Rotation Room: Aerospace Medicine, 1966, pp. 259-261.

Wood, C. D., and Graybiel, A. Evaluation of Sixteen Anti-Motion Sickness Drugs. vol. 39, 1968, pp. 1341-1344.