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KC-135 and Other Microgravity Simulations

Summary Report

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ANALYTIC
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Space and Life Sciences Directorate
Medical Sciences Division

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National Aeronautics and
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Lyndon B. Johnson Space Center
Houston, Texas 77058-3696

KC-135 and Other Microgravity Simulations
Summary Report - August 1, 1999

National Aeronautics and Space Administration
Lyndon B. Johnson Space Center

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PREFACE

This document represents a summary of medical and scientific evaluations conducted aboard the KC-135 from June 20, 1998 to June 20, 1999. Included is a general overview of KC-135 activities manifested and coordinated by the Life Sciences Research Laboratories. A collection of brief reports that describes tests conducted aboard the KC-135 follows the overview. Principal investigators and test engineers contributed significantly to the content of the report describing their particular experiment or hardware evaluation. Although this document follows general guidelines, each report format may vary to accommodate differences in experiment design and procedures. This document concludes with an appendix that provides background information concerning the KC-135 and the Reduced-Gravity Program.

NASA Photo: 96_05261

Documents available from:

NASA Center for Aerospace Information
7121 Standard
Hanover, MD 21076-1320

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Overview of KC-135 Flight Activities sponsored by the Life Sciences Research Laboratories, June 20, 1998 - June 20, 1999

During this reporting period of June 20, 1998 - June 20, 1999, five weeks were set aside for KC-135 flights sponsored by the Life Sciences Research Laboratories (LSRL). In addition, we were able to obtain seating during five weeks for LSRL customers with other organizations sponsoring the flight weeks. A total of 41 flights with approximately 40 parabolas per flight were completed. The average duration of each flight was 116 minutes. The LSRL KC-135 Coordinator assisted principal investigators and test engineers of 38 different experiments and hardware evaluations in meeting the necessary requirements for flying aboard the KC-135 and in obtaining the required seating and floor space. A total of 336 seats were purchased by LSRL customers, with 296 of these supporting customers outside of Medical Sciences. The number of seats sold and number of different tests flown by flight are provided below:

Flight Week	Seats Sold	# Tests Flown	Sponsor
July 7 - 10, 1998	46	4	LSRL
July 21 - 23	14	3	Crew Systems
August 25 - 27	55	4	LSRL
October 20 & 22	18	3	Ellington
October 27 - 30	33	3	LSRL
November 9 - 13	30	2	LSRL
March 16 - 20, 1999	15	4	Undergraduate Program
March 23 - 27	25	5	Undergraduate Program
April 20 - 23	36	6	"Fly High" Program
June 8 - 11	64	4	LSRL

Support was provided to the Undergraduate Program during weeks in March and to the "Fly High" high school student program during April 1999. Local and major network radio and television journalists accompanied the students on some of these flights. The inflight experiments were supported by a large ground crew from the respective university or high school.

Other LSRL sponsored KC-135 flight weeks are scheduled for July 20 - 23, July 27 - 30 and September 14-17, 1999. Support will also be provided to college investigators participating in the Undergraduate Program (part 2) during three weeks in August 1999.

Additional flights will be added throughout the remainder of the calendar year to accommodate LSRL customers as needs arise.

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Medical and Scientific Evaluations aboard the KC-135

2000025616

S1-52

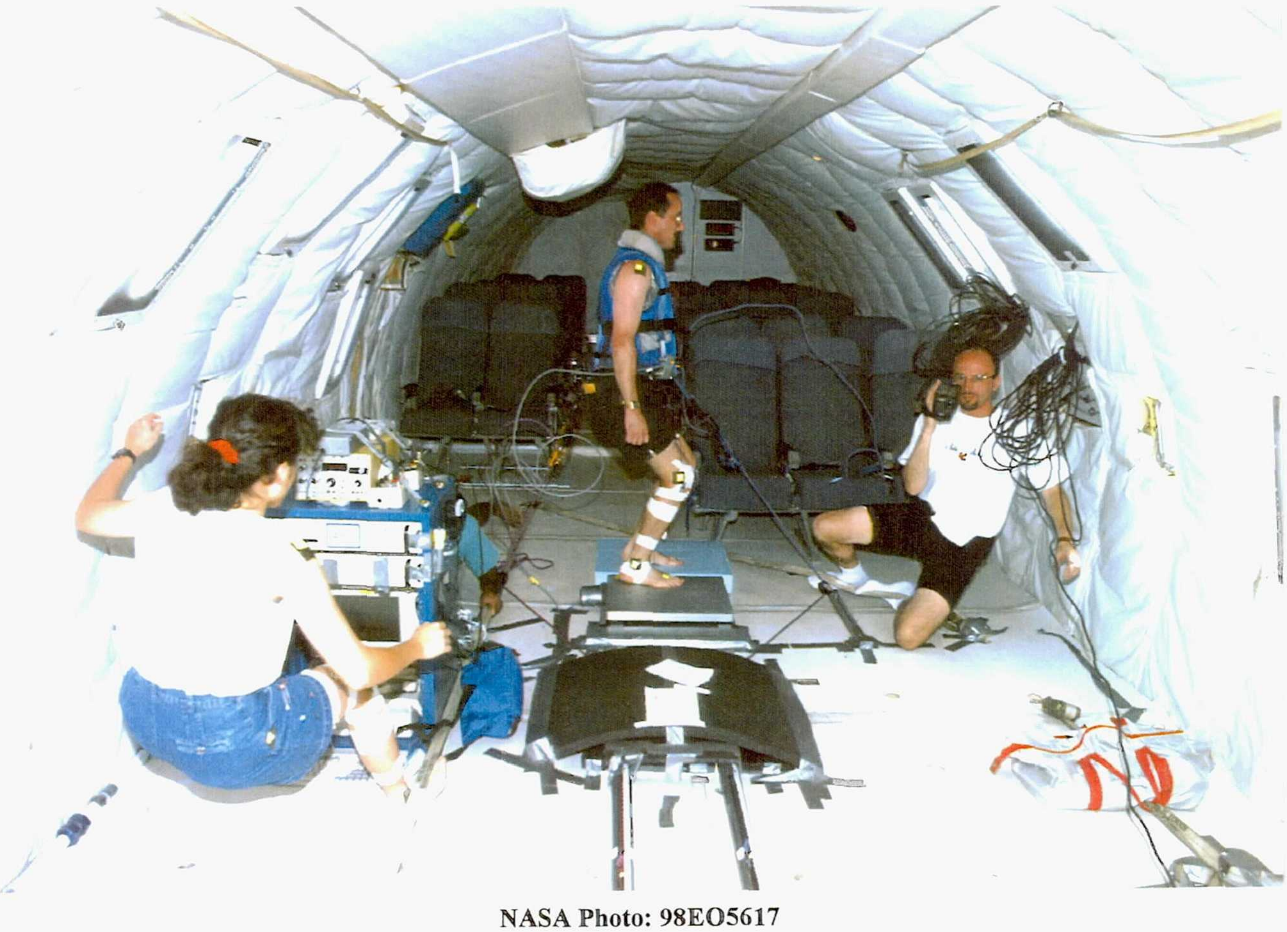
434219

TITLE:
Lower Limb Response to Impact Loads in 1G and Micro-G

FLIGHT DATES:
July 7-9, 1998

PRINCIPAL INVESTIGATORS:
Brian Davis, Ph.D., The Cleveland Clinic Foundation

CO-INVESTIGATORS
Helen E. Kambic, M.S., The Cleveland Clinic Foundation
Mark D. Grabiner, Ph.D., The Cleveland Clinic Foundation
James Sferra, M.D., The Cleveland Clinic Foundation



NASA Photo: 98EO5617

GOAL:

The overall goals of this study are 1) to demonstrate that jumping exercises may be more effective and efficient than current exercises performed in zero-gravity with respect to

maintaining bone density and muscle strength; 2) to validate the zero-gravity simulator as an appropriate substitute for true zero-gravity experiments during development of an optimum exercise regime; and 3) to quantify relationships between external loading profiles and internal bone strains.

OBJECTIVES:

The objectives of the test are to collect experimental data that can be used to validate and complement results previously collected during human subject experiments in a zero-gravity simulator and in 1G and during cadaver foot impact experiments in which bone strains were directly measured. We plan to gather non-invasive data for a total of eight human subjects over the course of two KC-135 flight days.

INTRODUCTION:

This experiment was performed in the third year of a three-year research study funded by NASA (NAGW-5006, Code UL) to look at exercise-based countermeasures to space flight induced bone loss. The first two years of the study involved experiments with human subjects in 1G and in a zero gravity simulator, and with cadaver feet in impact tests. The third year of the study entailed two scheduled flights on the KC-135 to perform some experiments involving tethered jumping exercises in a true (or near) zero-gravity environment in order to validate and elucidate our findings in the preceding experiments.

METHODS AND MATERIALS:

The experiments entailed maximum effort countermovement jumps performed by the subject during each zero-gravity period of the parabolic flight path. Subjects stood on a force plate and were tethered to the floor with cords attached to a waist harness. The tension in the cords were adjusted to restore some percentage of the body weight during the zero-gravity periods as described below. From these data, percentage of eccentric and concentric muscle activity, maximum force and rate of loading, impact velocity and peak accelerations will be determined. All data (except video) were collected via a rack-mounted personal computer.

Subjects

Eight subjects flew over a period of three days. The subjects met age, height and weight requirements such that they fell within the limits of age, height, and weight of typical astronauts in these respects:

Female; Min. age=30 yrs., max. age=41.1 yrs.
min. mass=46.8 kg, max. weight=68.4 kg
min. height=152.1 cm, max. height=172.1 cm

Male; Min. age=32 yrs., max. age=46 yrs.
min. mass=62.2 kg, max. weight=95.8 kg
min. height=162.85 cm, max. height=189.8 cm

Instruments
The JSC Ariel motion analysis system captured 3D motion data for one leg, and provided hip, knee and ankle flexion angles. Data collected were force (via a force plate), calcaneal and tibial acceleration (via skin-mounted accelerometers), aircraft acceleration (via floor-mounted accelerometer), flexor muscle activity (via skin-mounted EMG transducers), and motion (via video camera).

Procedure
Data were collected at 960 Hz for 30 seconds during parabolas. During each period of zero gravity, the subject was instructed to perform countermovement, maximum effort jumps. Two levels of tension in the bungee harness system were investigated, corresponding to 60% and 75% body weight.

RESULTS:

The total number of jumps accomplished over the three flight days are summarized below:

Flight Day: 7-7-98 Total Number of Parabolas Flown: 44

Subject 1	62 jumps over 9 parabolas
Subject 2	25 jumps over 3 parabolas
Subject 3	69 jumps over 7 parabolas

Flight Day: 7-8-98 Total Number of Parabolas Flown: 8

Subject 4	43 jumps over 5 parabolas

Flight Day: 7-9-98 Total Number of Parabolas Flown: 44

Subject 5	24 jumps over 4 parabolas
Subject 6	33 jumps over 5 parabolas
Subject 7	26 jumps over 4 parabolas
Subject 8	39 jumps over 6 parabolas

DISCUSSION:

Data were collected for all eight subjects. The process of changing tensions in the bungee harness system, changing subjects, and instructing subjects on performing jumps, became more efficient with increased experience on the KC-135. Data are being reduced jointly by NASA Johnson Space Center and the Cleveland Clinic Foundation.

CONCLUSION:

It is anticipated that this investigation will not only give insight into effective countermeasures for space flight-induced osteoporosis, but will also establish new techniques for quantifying internal bone deformations and directly link muscle actions, external loads and internal bone deformations.

REFERENCES:

Davis, B.L. (1991) A biomechanical investigation of simulated zero-gravity locomotion. Unpublished Doctoral Dissertation, The Pennsylvania State University.

Davis, B.L., and Cavanagh, P.R. (1993) Simulating reduced gravity: a review of biomechanical issues pertaining to human locomotion. *Aviation, Space, and Environmental Medicine*, 64, 557-566.

Davis, B.L., Cavanagh, P.R., Sommer, H.J., Wu, G (1995) Ground reaction forces during locomotion in simulated microgravity. *Accepted for publication in Aviation Space and Environmental Medicine*

PHOTOGRAPHS:

98EO5564 to 98EO5572
98EO5604 to 98EO5605
98EO5612 to 98EO5620

VIDEO:

Zero-G week of 7-7-98, PMU: 11/46527; Reference Master: 615718

Videos available from Imagery and Publications Office (GS4), NASA/JSC.

2000025617

TITLE:
Evaluation of RME 1318/TVIS Configuration C New ISS Restraint Harness and Modified Subject Load Device (SLD)

52-54

FLIGHT DATES:
July 7-10, 1998

434227

PRINCIPAL INVESTIGATORS:
Laura L. Bostick, Wyle Life Sciences
Don Schmalholz, NASA/Johnson Space Center

NASA Photo: 98EO5652

GOAL:

A new Treadmill (TM) Subject Restraint System was developed for the International Space Station (ISS) which included:

- New ISS Restraint Harness
- Modified Subject Load Device (SLD)

This investigation evaluated the operation of the New ISS Restraint Harness and Modified Subject Load Device (SLD) in zero-gravity conditions, in preparation for a flight test on STS-93 as part of RME 1318, TVIS Configuration C.

OBJECTIVES:

Although the treadmill system had flown numerous times on the KC-135 and on the Shuttle, the new Treadmill (TM) Subject Restraint System had not been tested in zero-gravity conditions.

The objectives of this investigation were:

A. To evaluate the New ISS Restraint Harness and Modified Subject Load Device (SLD) for physical comfort, stability, and effectiveness for exercise at different restraint loads.

B. To compare load variance of the modified SLDs which will fly on STS-93 and ISS (cam design) vs. the SLDs which flew on STS-81 and STS-84 (constant-radius hub design).

C. To identify operational constraints with the cam design SLDs.

METHODS AND MATERIALS:

Equipment Description:

TVIS Configuration C
Hardware Components
Required for KC-135 Flight

QTY	ITEM
1	ISS TM
1	TVIS Control Panel Power/Data Cable
2	TVIS SLD Power/Data Cables
1	TVIS Motor Box Power/Data Cable
2	Subject Load Devices

2	TM Motor Box Assy's
1	TM Electronics Box
2	TM Transfer Cases
4	Elevated Studs
4	TM Spacers
3	ISS Restraint Harnesses
3	PC MCIA Cards
2	SLD Adapter Plates

Protocol:

Four seats each on four days were required to perform this study. Two subjects ran per day:

Subject 1 - 10 parabolas with old SLDs
Subject 1 - 10 parabolas with new SLDs
Subject 2 - 10 parabolas with old SLDs
Subject 2 - 10 parabolas with new SLDs

The subjects were not informed of which SLDs were the "old" version and which were the "new" version. Comments were recorded by the operators throughout the flight, and the subjects filled out a questionnaire after the flight.

The 2 operators were responsible for changing out the SLDs, helping spot and load the subject, taking data, etc.

While the actual procedure varied from parabola to parabola and day to day in order to accomplish the desired test objectives, a typical test sequence followed the STS-84 In-flight TM Operating Procedures.

RESULTS:

The Subject Load Devices were modified to improve the slope of the Force versus Extended Distance curve of the Treadmill Subject Load Device (SLD) such that it is closer to zero (i.e., constant load). After the KC-135 flights, several meetings were held with the crew office and engineering directorate. It was determined that the Modified Subject Load Device (cam design) did not provide a significant improvement in load variance, so this design was discarded for STS-93 and ISS. A Series Bungee System is currently in work as an alternative. The ISS Restraint Harness is being modified to incorporate more adjustability and "stretchier" material across the shoulders.

DISCUSSION/CONCLUSIONS:

Evaluation of this experiment hardware aboard the KC-135 yielded very useful data in the design and development of flight hardware. As hardware fabrications and modifications are completed, future evaluations aboard the KC-135 are anticipated.

PHOTOGRAPHS:

98EO5580 to 98EO5594
98EO5610 to 98EO5611
98EO5620
98EO5625 to 98EO5653
98EO5730 to 98EO5752

VIDEO:

Zero-G week of 7-7-98, PMU: 11/46527; Reference Master: 615718

Videos available from Imagery and Publications Office (GS4), NASA/JSC.

20000025618

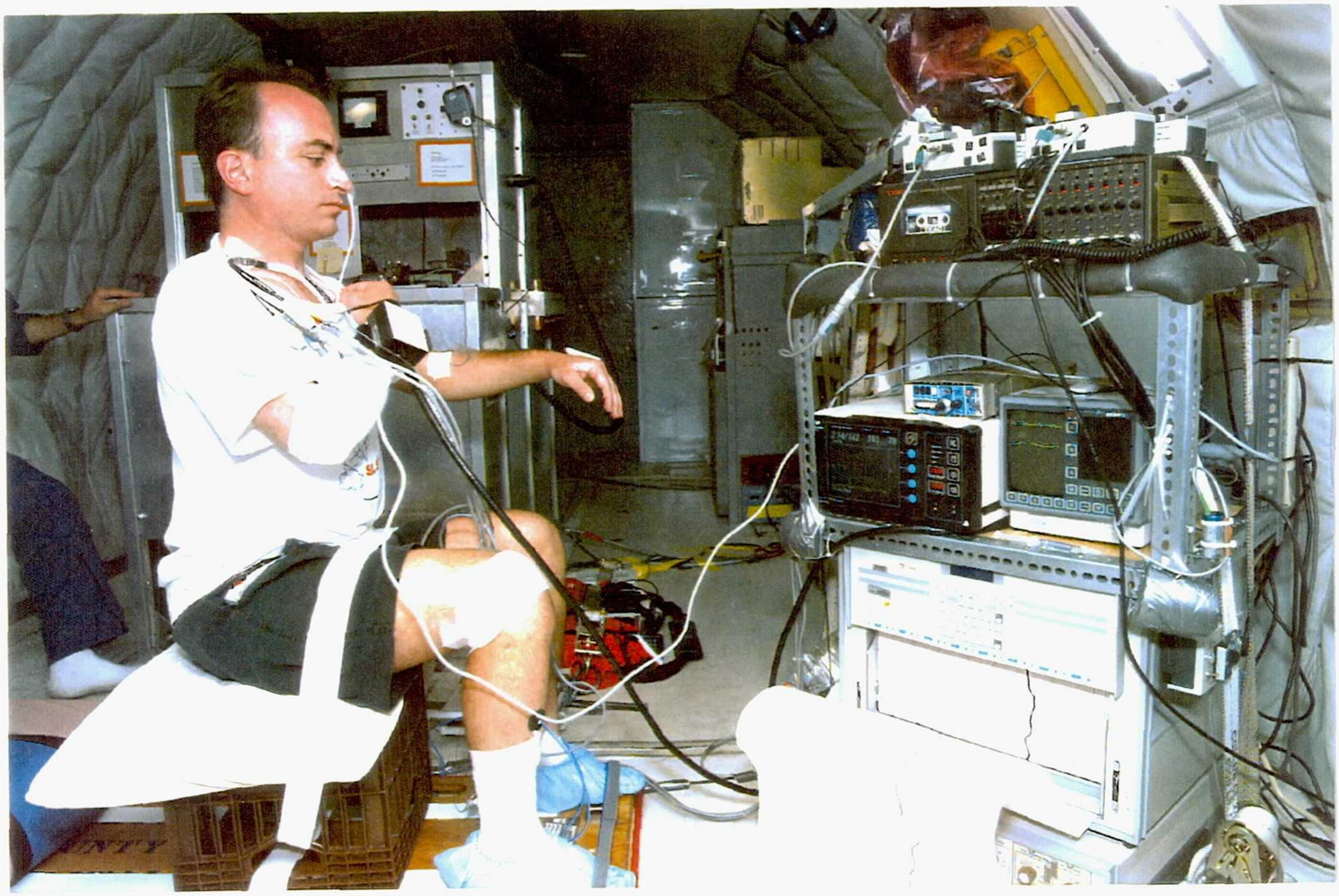
TITLE:
Physiologic Pressure and Flow Changes During Parabolic Flight (Pilot Study)

53-52
434246

FLIGHT DATES:
July 7-10, 1998

PRINCIPAL INVESTIGATORS:
George Pantalos Ph.D, University of Utah

CO-INVESTIGATORS:
M. Keith Sharp Sc.D., University of Utah
John R. Mathias, M.D., University of Texas Medical Branch, Galveston
Alan R. Hargens, Ph.D., NASA AMES Research Center
Donald E. Watenpaugh, Ph.D.,University of North Texas
Jay C. Buckey, M.D., NASA/Johnson Space Center



NASA Photo: 98EO5757

GOAL:

Understanding of physiologic pressure and flow responses to varying levels of acceleration.

OBJECTIVE:

Obtain measurement of cutaneous tissue perfusion central and peripheral venous pressure, and esophageal and abdominal pressure in human test subjects during parabolic flight.

INTRODUCTION:

Hemodynamic data recorded during SLS-1 and SLS-2 missions have resulted in the paradoxical finding of increased cardiac stroke volume in the presence of a decreased central venous pressure (CVP) following entry in weightlessness. The investigators have proposed that in the absence of gravity, acceleration-induced peripheral vascular compression is relieved, increasing peripheral vascular capacity and flow while reducing central and peripheral venous pressure. This pilot study seeks to measure blood pressure and flow in human test subjects during parabolic flight for different postures.

METHODS AND MATERIALS:

Four test subjects, one per flight, were instrumented with a laser Doppler cutaneous blood flow sensor, central and peripheral venous pressure catheters, and multi-pressure sensor nasogastric catheter. ECG and finger cuff blood pressure were also recorded. For each set of 10 parabola, test subjects assumed the launch, supine, 6 degree head-down tilt, or upright/seat posture. Blood pressure and flow data and acceleration were continuously recorded on a chart recorder and on an FM data tape recorder for later data analysis. Following a period of 1-G, level flight, a push-over maneuver was initiated followed by a normal parabolic flight profile.

RESULTS:

Preliminary descriptive results from postflight review are presented here. Entry into weightlessness reduced CVP and intraesophageal pressure (IEP) below 1-g values (3-4 mm HG) for all recumbent postures, but increased CVP and IEP (O-4 mm HG) in the seated posture. Weightlessness decreased intrabdominal pressure (IAP) (3-5 mm HG) for all postures. During hyperacceleration CVP and IEP usually increased above 1-G values, more so in recumbent than in the seated posture, and IAP increased (4-8 mm HG) independent of posture. The reductions in CVP, IEP and IAP during weightlessness for the recumbent postures support the hypothesis. Elevation of CVP and IEP during weightlessness for the seated posture may result from a headward shifting of abdominal contents and blood. The change in pressure with entry into weightlessness in the 6 degree head-down tilt posture questions the validity of this ground-based model for acute response to weightlessness.

DISCUSSION/CONCLUSION:

As results reported above are preliminary, in-depth analysis of the data will continue. Future experimentation aboard the KC-135 is anticipated.

PHOTOGRAPHS:

98EO5595 to 98EO5599
98EO5668
98EO5700 to 98EO5702
98EO5753 to 98EO5770

VIDEO:

Zero-G week of 7-7-98, PMU: 11/46527; Reference Master: 615718

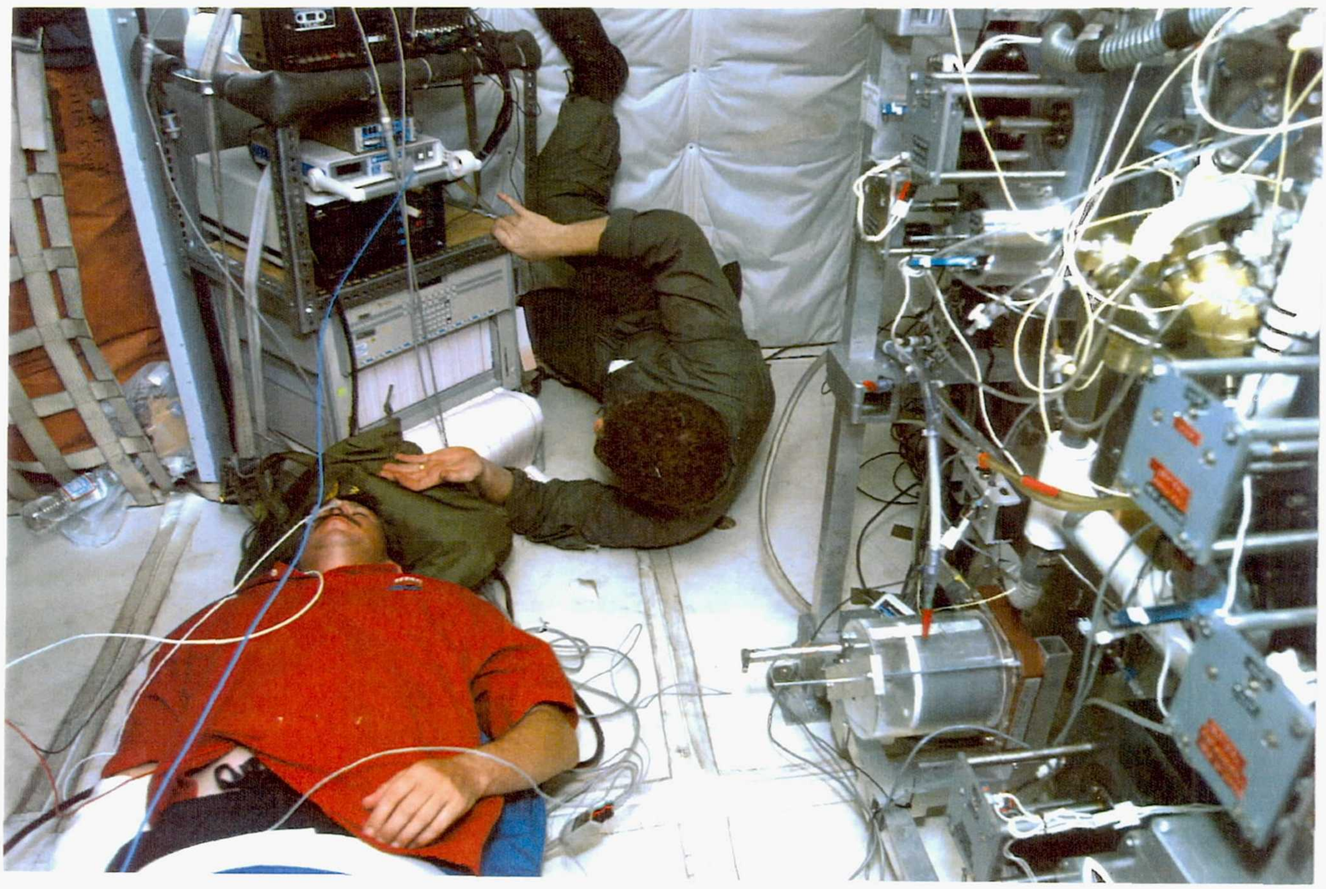
Videos available from Imagery and Publications Office (GS4), NASA/JSC.

TITLE:
Modeling of Cardiovascular Responses to Weightlessness

FLIGHT DATES:
July 7-10, 1998

PRINCIPAL INVESTIGATORS:
M. Keith Sharp, Sc.D., University of Utah

CO-INVESTIGATORS:
George Pantalos, University of Utah
Kevin D. Gillars, University of Utah



NASA Photo: 98EO5595

GOAL:

Understanding of cardiac and vascular bed response to varying levels of acceleration

OBJECTIVE:

Obtain measurement of blood pressure, blood flow and volume distribution in a life-size, physical model of the cardiovascular system.

INTRODUCTION:

Hemodynamic data recorded during SLS-1 and SLS-2 missions have resulted in the paradoxical finding of increased cardiac stroke volume in the presence of a decreased central venous pressure following entry in weightlessness. Chronic observations from space flight also describe a headward shift of the circulating fluid volume. The investigators have proposed that in the absence of gravity, acceleration-induced effects such as hydrostatic pressure and peripheral vascular compression are relieved, increasing central and peripheral vascular capacity and flow while reducing central and peripheral venous pressure and augmenting cardiac diastole function. This investigation seeks to measure key hemodynamic parameters to assess the purely biomechanical component of these observations in the acute-phase response during parabolic flight for different models postures.

METHODS AND MATERIALS:

An instrumented, life-size model of the cardiovascular system with regional vascular component was flown in the KC-135 aircraft. For each flight, the cardiovascular model was oriented in the launch, supine, or 6 degree head-down tilt, or upright posture. Cardiovascular data and acceleration were continuously recorded on a chart recorder and on an FM data tape recorder for later data analysis.

RESULTS:

Data are currently being analyzed. Early results of the circulating volume data indicate that in the upright posture when compared to the 1-G condition, nearly 300 ml of the fluid shift headward from the caudal and the peripheral venous pool elements of the model with entry into weightlessness. For the launch posture when compared to the 1-G condition, nearly 400 ml of fluid shifted into the peripheral venous pool from the cranial and central regions and an additional 100 ml shifted into caudal venous compliance elements. For both postures, the fluid shift was rapid and essentially completed in about 10 seconds into the period of weightlessness. For the supine posture, there was no appreciable fluid shifting with transition into weightlessness. Pressure and flow changes also indicated a slight footward shift of fluid with entry into weightlessness for the 6 degree head-down tilt posture which questions the validity of this ground-based model for acute response to weightlessness.

DISCUSSION/CONCLUSION:

As results reported above are preliminary, it is too early in our analysis to report other cardiac and vascular function data results. In-depth analysis of this data collected aboard the KC-135 will continue.

PHOTOGRAPHS:

98EO5595
98EO5697
98EO5698
98EO5699

VIDEO:

Zero-G week of 7-7-98, PMU: 11/46527; Reference Master: 615718

Videos available from Imagery and Publications Office (GS4), NASA/JSC.

2000025620

55/52

434254

TITLE:
ISS Medical Checklist Procedures Validation and Training

FLIGHT DATES:
July 10, 1998
July 21, 1998

PRINCIPAL INVESTIGATORS:
Tom Marshburn, M.D., NASA/Johnson Space Center
Julie Goode, Wyle Life Sciences

NASA Photo: 98EO5729

GOAL:

1. To validate medical procedures for ISS
2. To validate crew time requirements to perform procedures
3. To identify operational deficiencies and issues, particularly regarding division of tasks between operators
4. To obtain insight from astronaut physicians

OBJECTIVE:

1. Obtain astronaut input and feedback on procedures
2. Satisfy Systems Operational Data File (SODF) Procedure Verification (PV) requirements
3. Identify missing, illogical, or unnecessary steps to decrease performance time and to minimize complexity of Advanced Cardiac Life Support (ACLS) procedures.

INTRODUCTION:

The Health Maintenance System (HMS) hardware will be used to support a medical contingency for the International Space Station (ISS). During two test flights, the procedures for performing ACLS were evaluated to determine the required level of detail, assess the logic of the steps and division of tasks among crew members.

METHODS AND MATERIALS:

The following protocols were followed where the astronaut physicians were Crew Medical Officer (CMO) 1 and CMO 2.

Series #1: CMO 1 - CPR
CMO 2 - CMRS and Bag/Valve/Mask (BVM) deploy
Proceed up to first defibrillation.

Series #2: CMO 2 - CPR
CMO 1 - Defibrillator deploy
Proceed up to first defibrillation.

Series #3: CMO 2 - CPR, CMRS deploy
CMO 1 - Defibrillator deploy

Series #4: "Free-floating" defibrillation

The following equipment was used to support the test.

Advanced Life Support Pack (ALSP)
Respiratory Support Pack (RSP)
Defibrillator with ECG simulator
Crew Medical Restraint System (CMRS)
Mannequin (AmbuMan for Flight 1, ResusciAnnie for Flight 2)
Intubation head (for Flight 2 only)
IV arm
Audio recorder, stop watch, data log
Test fixture (ISS floor) with seat track interfaces

Subjects
There were no human subjects for this test. Astronaut personnel acted as ISS crew members.

RESULTS:

CPR

Initial assessment and rescue breathing were performed simultaneously by cradling the patient. CPR was performed using two methods a) rescuer restraint with one hand, CPR with other hand b) rescuer with both feet on module wall, CPR with both hands against opposite module wall. CPR seems possible by placing legs under the CMRS to provide restraint. It was also possible with feet on ceiling, but rescue breathing was then problematic.

CMRS

The CMRS did not always click into the Seat Track Interface Adapters (STIAs). It was possible to place the CMRS into the STIAs without a secure mating. The CMOs found that one strap over the legs was sufficient to restrain patient for further procedures. All three CMRS patient restraints (legs, chest, head) were not necessary until transport. The CMO straps on the sides of the CMRS do not offer the CMO much restraint and made positioning for CPR difficult.

Defibrillator

The CMOs attached the defibrillator to the seat track on the same side of the CMRS as the operator. When the defibrillator was placed elsewhere such that the CMO was reaching over the patient, it was difficult to clear for the shock. The CMOs determined that the defibrillator pads should be placed on the patient, especially the back pad, prior to laying the patient on the CMRS.

ALSP and RSP

The CMOs found that the ALSP and defibrillator need to be deployed close to themselves and near the patient's head (on either side of the CMRS). It was noted that the Airway subpack once removed from the ALSP was difficult to restrain where the contents were accessible. In general, it was difficult to manage the amount of equipment that had to be deployed.

DISCUSSION/CONCLUSIONS:

It is difficult for one CMO to perform rescue breathing and chest compressions simultaneously, particularly when using two hands on the sternum. With minimal restraint, however, one CMO can cradle the patient and perform rescue breathing and assessment.

While the CMRS is easily deployed and is a good workstation for completion of full ACLS algorithms, initial defibrillation is significantly delayed by deploying the CMRS. To minimize the time to the first shock, initial defibrillation in "free-float" should be

considered or the use of an electrically isolating strap for patient restraint. Transfer to the CMRS could then be performed when it is possible to deploy it. If the CMRS is deployed, the time to the first shock can also be minimized by not using the CMRS shoulder straps and by having the STIAs nominally installed into the seat track. The time required to install the STIAs adds significant time to the CMRS deployment.

Because RSP and ALSP must be used together in a contingency it is recommended to have them stowed in a more integrated configuration. The addition of a strap so that the RSP travels as one unit on top of the ALSP may be a solution to be considered. The Airway subpack also needs a means of restraint to ALSP so that the Airway subpack contents are easily accessible to the CMO.

The tasks should be clearly divided in the procedures, instructing each CMO through a parallel flow. Finally, the defibrillator procedures should be in a quick fold out format that could be secured to a locker or floor. This format would free the CMO from page turning in a book format.

PHOTOGRAPHS:

98EO5711 to 98EO5729
98EO6041 to 98EO6042
98EO6044
98EO6046
98EO6048 to 98EO6049

VIDEO:

Zero-G week of 7-7-98, PMU: 11/46527; Reference Master: 615718
Zero-G week of July 21-23, 1998, PMU: 11/46611, Master: 615618

Videos available from Imagery and Publications Office (GS4), NASA/JSC.

2000025621

TITLE:
Blood Sampling Kit Evaluation

56/52

FLIGHT DATES:
July 21-22, 1998

434256

PRINCIPAL INVESTIGATORS:
Karen Gunter, Wyle Life Sciences

NASA Photo: 98EO6040

GOAL:

To evaluate components of the blood sampling kit during microgravity aboard the KC-135.

INTRODUCTION:

The blood sampling kit was designed for use during space flight. The kit contains all the components that astronauts require to obtain necessary blood samples in microgravity.

METHODS AND MATERIALS:

Subjects
One subject and two investigators participated in the evaluation of the blood sampling kit.

Instruments
The sampling kit flown onboard the KC-135 was stocked with 1.2 ml and 2.7 ml monovettes, 2 ml and 3 ml flush tubes, filling cartridges, EMLA disks and topical anesthetic creams.

Procedures
An intravenous (I.V.) catheter was placed in the left forearm of a medically qualified subject prior to the first flight and in the right forearm prior to the second flight. Blood samples were drawn through the catheter and heparin and saline injections were made during the microgravity portions of the KC-135 parabolic profiles.

One of the investigators wore the topical anesthetic EMLA disk during flight day one.

A comparison of usage of the 2 mL flush tube versus the 3 mL flush tube was made. The protocol that was followed was simple. The extension set was flushed in a series of ways.

a) 1 mL saline, 1 mL heparin---draw (1) 2 mL flush, draw (1) 2 ml EDTA
b) 1 mL saline, 1 mL heparin---draw (1) 3 mL flush, draw (1) 2 ml EDTA
c) 5 mL saline, 1 mL heparin---draw (1) 2 mL flush, draw (1) 2 ml EDTA
d) 5 ml saline, 1 mL heparin---draw (1) 3 mL flush, draw (1) 2 ml EDTA

This series was performed on day one and repeated on day two. The EDTA tubes were run on the Coulter, a hematology analyzer, for a complete blood count.

RESULTS:

The following observations were made as a result of the two flights:

1.2 ml vs 2.7 ml monovettes. The 1.2 ml monovettes did not function properly. This was due to the fact that the amount of "dead space" in the monovette is greater than the amount of blood (1.2 mL). Both experimenters tried to fill the PCBA cartridges with the 1.2 mL monovette and it was impossible.

2 ml vs 3 ml Flush tubes. The results from all the collections using the 2 ml and 3 ml flush tubes were consistent. There appeared to be no dilution from heparin in the extension set.

Filling cartridges. Filling cartridges in "Zero G" was problematic if the cartridge was air-locked. This study is still on going and will be completed on the ground. If requested, we could re-fly cartridges to verify any suggestions to filling.

EMLA disk vs cream. The tegaderm tore open half way through the flight. Video was taken of the open tegaderm. The disk began leaking on the outer edge, this may have been from unknowingly applying pressure to the disk. Both were removed during the flight after 3 hours. Approximately 7 hours later, skin redness was still observed at the point of application.

DISCUSSION:

1.2 ml vs 2.7 ml monovettes. 2.7 mL monovettes should be used. Filling the cartridge and mixing 2.7 mL monovette is easier and with the extra volume, repeat testing can be performed if necessary.

2 ml vs 3 ml Flush tubes. The results from 2 ml and 3 ml flush tube usage suggest that after a 2 mL flush you have whole blood. A 2 ml flush tube can be used to clear the extension set prior to blood collection.

Filling Cartridges. Additional evaluation of filling cartridge usage in “Zero G” is required. Placing the tip of blunt cannula into the base of the column and filling slowly seems to help. The cannula tip may need to be shortened.

EMLA disk vs cream. Plans are to use the EMLA disks, and they have been ordered for flight. Application of the EMLA will be used during BDC to observe any reactions the subject may have. Consideration is being given to wrapping the EMLA disk with a wrist wrap to prevent leaking when it is worn for more that 1 hour. The name of the EMLA disk may be changed to Topical Anesthetic Disk (TAD).

CONCLUSION:

Plans are being made to verify the numbers of each consumable to be flown. Gray tape is a key element to use to help maintain small pieces and parts during KC-135 and space flights.

PHOTOGRAPHS:

98EO6040
98EO6043
98EO6045
98EO6047
98EO6173 to 98EO6180
98EO6183 to 98EO6187
98EO6190 to 98EO6192

98EO6194 to 98EO6195

VIDEO:

Zero-G week of July 21-23, 1998, PMU: 11/46611, Master: 615618

Videos available from Imagery and Publications Office (GS4), NASA/JSC.

2000025622

TITLE:
Ergonomic Evaluation of the Foot Restraint Equipment Device (FRED)

FLIGHT DATES:
July 22-23, 1998

57/54
434259

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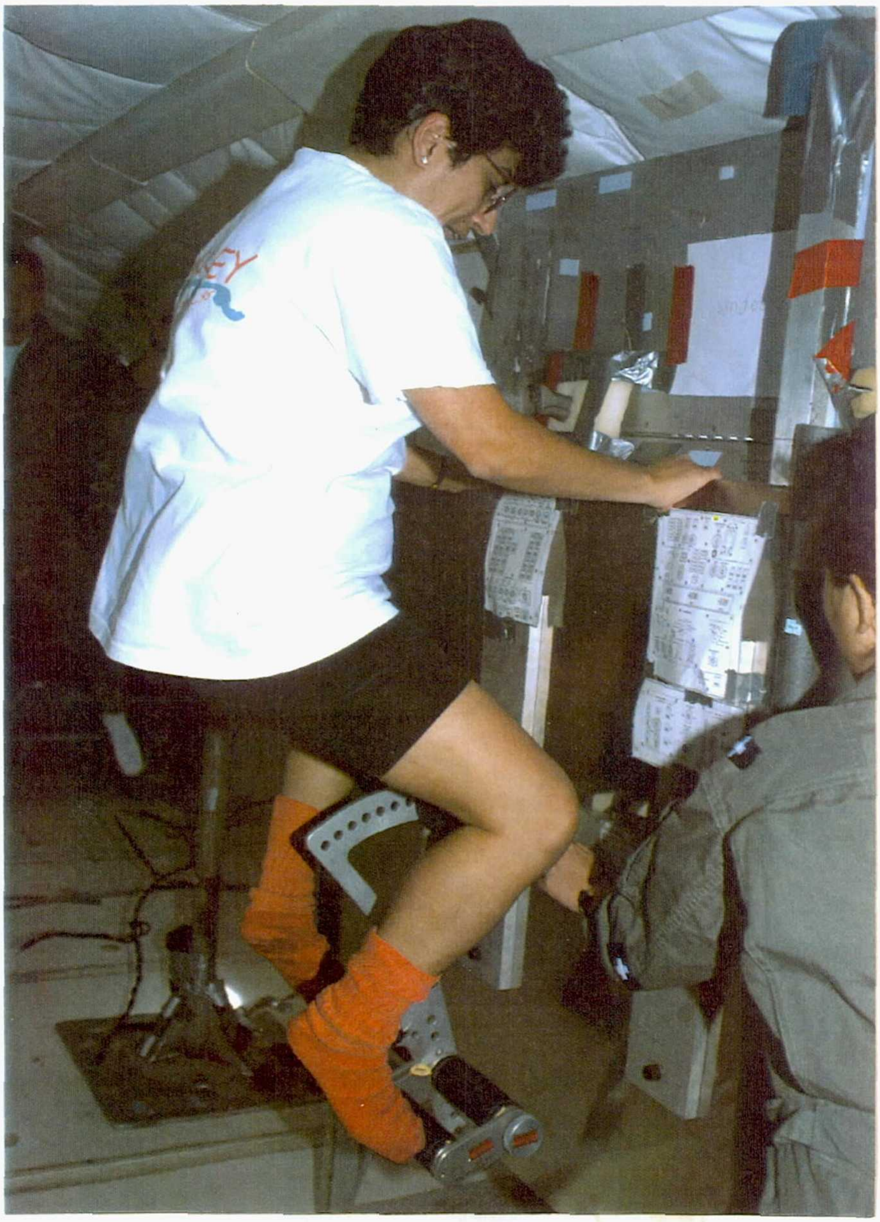

NASA Photo: 98EO6189

GOAL/OBJECTIVE:

The purpose of this evaluation was to identify user interface issues of the Foot Restraint Equipment Device (FRED) and crew restraint requirements for the Remote Manipulator System (RMS) workstation.

INTRODUCTION:

Within the scope of the Microgravity Workstation and Restraint Evaluation project, funded by the NASA Headquarters Life Sciences Division, evaluations were proposed to be conducted in ground, KC-135, and/or Shuttle environments to investigate the human factors engineering (HFE) issues concerning confined/unique workstations, including crew restraint requirements. As part of these evaluations, KC-135 flights were conducted to investigate user/ workstation/ restraint integration for microgravity use of the FRED with the RMS workstation. This evaluation was a pre-cursor to Detailed Supplementary Objective (DSO) - 904 on STS-88. On that mission, a small-statured astronaut will be using the FRED restraint while working at the Aft RMS workstation. The DSO will collect video for later posture analyses, as well as subjective data in the form of an electronic questionnaire.

This report describes the current FRED KC-135 evaluations. The primary objectives were to evaluate the usability of the FRED and to verify the DSO in-flight setup. The restraint interface evaluation consisted of four basic areas of restraint use: 1) adjustability; 2) general usability and comfort; 3) usability at the RMS workstation; and 4) assembly and disassembly.

METHODS AND MATERIALS:

A team of six test conductors evaluated the FRED prototype along with a mockup of the RMS workstation for two flights onboard the KC-135 in July of 1998. Four of the participants were experienced KC-135 flyers who have not previously been affected by motion sickness; two were first-time fliers. The evaluators represented a range of anthropometry from 5th percentile Japanese female to 95th percentile American male. The team evaluated viewing location and reach issues as well as crew restraint requirements and suggested changes and/or made other recommendations as appropriate.

This report is intended to document HFE findings based on in-flight observation and experience as well as subjective questionnaire data provided by five evaluators. Questionnaire items were rated on a scale of 1 - Completely Disagree to 7 - Completely Agree. Table 1 shows a complete list of FRED/RMS issues that were included in the questionnaire along with their average ratings. All of the participants ratings were on the same side of the scale (either agree or disagree) except where noted. The findings will be discussed in the following four sections.

RESULTS AND DISCUSSION:

Ingress/Egress and Adjustability:	AVERAGE RATING	Usability at the RMS Workstation:	AVERAGE RATING
Ingress performed easily	6.4	Reach to THC was acceptable	6.4
Egress performed easily	6.8	Reach to RHC was acceptable	6.4
Adjustability at the rack interface point (arm) was acceptable	5.2	Looking out Aft port window was acceptable	6.0
"Knee" joint location was acceptable	5.6	Looking at CCTV monitor was acceptable	7.0
"Knee" joint adjustability was acceptable	5.6	Reach to CCTV controls was acceptable	6.3
"Foot" joint location was acceptable	6.2	Reach to panel A8L was acceptabl	6.0
"Foot" joint adjustability was acceptable	5.4	Comfortable distance from the workstation was maintained	5.8
Height adjustability was acceptable	4.8	Angle relative to the workstation was acceptable	5.2
Adjustability while restrained was acceptable	3.3	Restraint able to provide optimal performance of the task	6.0
Adjustments were performed by one operator	5.5	Easy to find optimal restraint position	4.6
Adjustments were performed with one hand	1.4		
General Usability/Comfort:		**Assembly/Disassembly:**	
Able to support maximum reach	6.4	The leg bar was easily assembled to the rack interface bar	2.0
Allowed maintaining a stable posture	6.4	Knee pads and shaft were easily assembled to the silver bar	5.0
Provided a stable posture	5.4	Foot pads and shaft were easily assembled to the silver bar	5.0
Rack interface joint (mounting assembly) was stable	3.0	Disassembly was performed easily	5.8

Table 1. Questionnaire issues and average ratings. A rating of 7 = Completely Agree; 4 = Neutral; 1 = Completely Disagree.

Ingress/Egress and Adjustability

Both ingress and egress of the restraint were given acceptable ratings (average ratings of 6.4 and 6.8, respectively). Both the knee and foot joint locations and adjustability were also acceptable (average ratings of 5.6, 6.2, 5.6, and 5.4, respectively). In addition, the adjustability of the joint at the attachment mounting assembly was rated as acceptable (average rating of 5.2). The height adjustability was rated as marginally acceptable (average rating of 4.8). Participants agreed that adjustments can be performed by one operator

(average rating of 5.5), however, not while restrained (average rating of 3.3). The ability to adjust the restraint while ingressed has been replaced by discrete adjustment points, which provide more stability. Finally, participants disagreed that adjustments can be performed with only one hand (average rating of 1.4). Again, this was expected due to the discrete nature of the adjustment points -- participants were required to unscrew and remove the knee or foot pad shafts to adjust. However, it should be noted that operators will need an additional restraint (i.e. foot loops) to keep them stable while performing adjustments to the FRED.

General Usability and Comfort

Based on questionnaire responses, the restraint was able to support maximum reach (average rating of 6.4). All but one also agreed that the restraint provided a stable posture and allowed them to maintain this posture (average ratings of 6.4 and 5.4). One small-statured participant disagreed that the restraint was stable (rating of 3.0). However, this may have been due to the unstable KC-135 environment (i.e. negative-gravity periods). The joint on the attachment mounting assembly was rated as not stable (average rating of 3.0). Participants commented that the clutch/center hub slipped often. None of the participants reported experiencing any discomfort in their lower backs, thighs, calves, or feet. This result was expected due to the short periods of restraint use.

Usability at the RMS Workstation

A number of mockups of Aft RMS workstation components were provided for the two flights, including: Translational Hand Controller (THC), Rotational Hand Controller (RHC), CCTV monitors, and paper representations of the CCTV control panel, panel A8U, panel A8L, and the aft port window. Participants were tasked to reach or view these components. Reach to the THC and RHC were both rated as acceptable (average ratings of 6.4 for both). The ability to look at the CCTV monitors and to look out the aft port window were also rated as acceptable or completely acceptable (average ratings of 6.0 and 7.0, respectively). Finally, reach to the CCTV control panel and panel A8L were rated as acceptable (average ratings of 6.3 and 6.0, respectively).

Participants agreed that the FRED allowed them to maintain a comfortable distance from the workstation (average rating of 5.8), as well as a comfortable angle (average rating of 5.2). In addition, participants rated the restraint's ability to provide for optimal performance of the task as acceptable (average rating of 6.0). However, ratings were slightly lower for the ease of finding the optimal position (average rating of 4.6). One large-statured participant rated this as not easy (rating of 3.0). However, another participant commented that this would become easier with practice.

Assembly and Disassembly

Assembling the knee pads and foot pads to the leg bar were rated as acceptable (average ratings of 5.0 for both). However, four participants commented that the threads were

difficult to engage and that it took some effort to line the knobs up correctly so that the threads do not become stripped. Knobs with finger knurls to supply a better grip while tightening were recommended. The task of assembling the leg bar to the arm was rated as unacceptable (average rating of 2.0). Participants commented that it took quite a bit of effort to line up the holes and keep the two pieces stable and flush while connecting the short screw. Note that some of the difficulty in aligning pieces may have been a factor of the KC-135 environment (i.e., negative gravity periods). In addition, the orientation of the arm and leg bar pieces was not intuitive -- it was unclear to which side of the arm and in which direction the leg bar attaches.

Participants had no difficulty in disassembling the FRED (average rating of 5.8). However, participants commented that having Velcro on every piece would have been helpful for restraining items during assembly and disassembly. One participant commented that a one person assembly/disassembly would definitely require the use of a foot restraint.

CONCLUSIONS:

Recommendations for potential FRED modifications:

(1) Screws/knobs difficult to align and engage, sometimes became stripped.
RECOMMENDATION: The addition of a rubber piece at the entranceway to the screw holes would aid in screw/knob alignment and may help to prevent stripping and jamming.

(2) Difficulty in aligning leg bar with arm.
RECOMMENDATION: The addition of labels indicating which side of the arm the leg bar lies against would promote efficiency in assembly. Also, labels indicating which direction the angle adjustment should face (either into or away from the workstation) would be beneficial for efficient assembly, as well as, added stability. Another approach is to provide a sketch of the assembly as part of the procedure.

(2) Knobs difficult to tighten.
RECOMMENDATION: The addition of knurls to the FRED knobs will aid in gripping the knob and tightening.

(3) Difficult to contain FRED components while assembling/disassembling.
RECOMMENDATION: The addition of Velcro to the components will aid in assembly and disassembly of the FRED by one operator, since both hands are needed to perform the task.

While adjustability mechanisms and stability need some modifications, the design interface was acceptable overall, especially in terms of the RMS operator tasks. One participant commented, once properly adjusted the FRED was very comfortable and would clearly enhance RMS operations.

PHOTOGRAPHS:

98EO6160 to 98EO6172
98EO6181 to 98EO6182
98EO6188 to 98EO6189
98EO6193
98EO6211 to 98EO6221

VIDEO:

Zero-G week of July 21-23, 1998, PMU: 11/46611, Master: 615618

Videos available from Imagery and Publications Office (GS4), NASA/JSC.

TITLE:
Vestibular Interactions During and After Head Movements in Hypergravity: Constant 2G Acceleration with Negligible Angular Velocity

FLIGHT DATES:
August 25-27, 1998

PRINCIPAL INVESTIGATORS:
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NASA Photo: 98EO7349

GOAL:

The goal of this experiment is to determine and quantify human responses to motion in increased gravitational fields (hypergravity).

OBJECTIVE:

Objectively measure changes to the human vestibulo-ocular reflex (VOR) and gastric myoelectrical activity of the stomach under the influence of increased gravitational force (hypergravity).

Subjectively measure nausea and visually perceived motion resulting from head movements under hypergravity.

INTRODUCTION:

The G-excess illusion has been implicated in a significant number of aviation mishaps involving loss of situation awareness. The G-excess illusion can occur when head movements are made in an elevated gravity field, such as in a banked turn or in an accelerating space vehicle. This can cause illusory attitude changes of as much as 90°, depending on type and rate of head movement. In addition, head movements in an elevated gravity field can lead to the development of motion sickness symptoms. The level of motion sickness encountered during a preliminary hypergravity study performed on the KC-135 in 1991 could not be accounted for by coriolis cross coupling effects (the nauseating sense of tumbling produced by head movements in a rotating environment). We employed the KC-135 (as in the 1991 study) as a large centrifuge, flying in a banked turn to generate hypergravity (1.8G). We proposed to investigate the human physiological response to head movements during increased linear acceleration by measuring the vestibulo-ocular reflex (VOR). We recorded perceptual reports of visual illusions of motion as a result of these head movements. We also monitored the onset and progression of motion sickness symptoms during hypergravity with subjective symptom reporting and an objective measure of gastric activity (electrogastrogram). These experiments should lead to better understanding of the mechanism of the g-excess illusion and help develop effective countermeasures for pilots and astronauts returning to the relatively high gravity of the earth after adaptation to microgravity.

METHODS AND MATERIALS:

Motion Sickness/Nausea Profile Questionnaires (Pre-/In-/Post- Flight)

The subjects filled out the questionnaires prior to embarking and while onboard the aircraft. Questionnaires were filled out at each station shift (approximately every 25 min during the experiment) to assess cumulative effects and determine a baseline prior to each activity. Upon completion of hypergravity runs, each subject filled out a set of post flight questionnaires [Muth, 1996]. All subjects were provided emesis bags.

G-Excess Illusion (Inflight)

Pre-flight, subjects were instructed on the head movement sequences and given time to practice the protocols. They were assigned identification numbers and instructed on the order of station assignments. Inflight, subjects were seated on aircraft seats (from JSC-Aircraft Operations) in one of three test stations in a darkened portion of the aircraft (KC-

135 Blackout Curtains, Wyle Laboratories, Houston, TX). Three visual targets consisting of four inch squares of 1/4 inch plexiglas were placed in front and to each side of each subject testing station. The targets had 1/16 inch grooves cut in a cruciform pattern on the surface facing the subject. Each target, illuminated from the edge by a 6 volt incandescent lamp, produced a faint, but visible in the dark, crosshair target. The side targets were secured to the wall padding of the aircraft with velcro and tape, along with cardboard shields so that each subject could only see one set of targets. The targets in front of the VOR subjects were mounted to a 36 inch diameter fiberglass/stryofoam disk mounted to a tall camera pole (from JSC-Aircraft Operations) positioned approximately 43 inches from the subject's eyes. The perceptions station subject did not require a disk as this station was located at the front of the testing area, so the target was attached directly to the pole. All subjects and test participants wore audio headsets with boom microphones (David Clark, H10-60, Worcester, MA) or U.S. Navy flight helmets with boom microphones. A custom built audio amp/mixer provided audio between all active test participants. The test operator (TO) announced the start of each run when informed by the NASA test director (TD) and indicated which head movement sequence will be performed. Each subject held their gaze at the target in front of them for thirty seconds, and then, on cue from the TO, initiated the selected head movements. Each subject was accompanied by a subject observer (SO) in the adjacent seat. The SO provided any assistance as necessary and recorded subject perceptions of target motion. Each subject was instrumented with a three axis linear accelerometer (Entran Devices, EGA3-C-5D, Fairfield, NJ at the VOR stations or Analog Devices, ADXL05EM-3, Norwood, MA at the perceptions station), to provide gravito-inertial force data in head centered coordinates.

VOR Test Stations

In addition the two VOR test stations included head-mounted binocular near infrared video monitoring of test subject eye movements (Cohu, model 6514, San Diego, CA). The camera mounts were based on modified U. S. Navy flight helmets. Near visible infrared (IR) illumination will be provided by two light emitting diodes (LED's, Philips, ECG3017) per camera. At these stations, the SO were also responsible for adjusting the camera set up prior to each run. These stations included a cruciform of eight visible light LED's centered on the center visual target and mounted to the disk.. The SO turned these battery powered LED's on as instructed by the TO for subject video eye position calibration. The SO at these stations utilized nine inch video monitors (Panasonic TR930B or equivalent) to confirm focus and positioning of the video cameras (monitors were turned off and covered with blackout cloth during data runs).

All three test stations had videocameras (Cohu, model 1122, San Diego, CA) mounted to the camera pole to allow the TO to monitor all stations. In addition, a safety monitor (SM), present in the darkened chamber, was available to render assistance as necessary and secure any light leaks that arose. The SM had night vision goggles (Litton Electronic Devices, M973, Tempe, AZ) available, in addition to the two way audio communication system.

Motion Sickness in Hypergravity (Inflight)
A fourth test station was located outside of the darkened chamber. Four subjects on each flight were restrained (Hooker Custom Harness, 7-point restraint system, Freeport, IL) in NAMRL's gimbaled chair and passively oscillated by the SO in the roll plane plus and minus 45°. Both subject and SO were connected to the audio amp/mixer to allow communication with the TO. The test subject wore a black out sleep mask to occlude visual stimuli. A potentiometer attached to the chair output produced a voltage that was proportional to the angular position of the chair. A video camera (Cohu, model 1122, San Diego, CA) allowed the TO to monitor this test station. All subjects completed nausea profile and motion sickness questionnaires at the end of each 25 minute (approximately) rotation. Subjects gastric myoelectrical activity was recorded using electrogastrography.

Electrogastrography, a non-invasive technique for recording gastric myoelectrical activity of the stomach using surface electrodes was used as an objective supplement to modified Graybiel motion sickness and nausea profile scores. Data were recorded using field effect transistor (FET) type electrodes and a Digital Biolog (UFI, Morro Bay, CA). Three electrodes were placed on the test subject's abdomen: one along the left mid clavicular line one to two inches below the costochondral margin, one at the midpoint between the xyphoid process and the umbilicus, and the third (ground) on the rib cage of the subject's right side. Prior to electrode placement, the skin was shaved, if necessary, lightly abraded using Omniprep and a protective barrier (Mentor Shield Skin) was applied. Electrode impedances were checked after application to confirm an impedance less than 10 kohms .

Subjects
Twenty seven subjects participated in this experiment, all of whom had taken an aviation physiology course and passed either an Air Force Class III or Navy N-3 or N-1 physical. Eight subjects were recruited from the Naval Aviation Schools Command and the balance from the NASA-JSC Human Test Subject Facility (HTSF). The eight Navy subjects (all male) were junior officers awaiting primary aviation instruction. Four of the NASA subjects were female (15 male), and all were either NASA employees or recruited from the general public. All female subjects had negative urine human chorionic gonadotrophin (HGC) tests within 24 hours prior to flight. The average age of the test subject pool was 32 (median 30, mode 27, minimum 22, maximum 45)

Procedure
Subjects were briefed as a group on the morning of their flight on KC-135 safety and operations on the experimental procedures. Informed consent was obtained and documented using an informed consent form that was approved by the NASA-Lyndon B. Johnson Space Center's Institutional Review Board, and Protection of Human Subjects Committees at the Naval Aerospace Medical Research Laboratory and the Naval Medical Research and Development Command. Previous nausea and motion sickness questionnaires were distributed and tabulated prior to flight. The four subjects with the most motion sickness histories were selected to participate in the gimbaled chair (passive motion) station. The balance of each days subjects were then assigned to one of the three G-excess active head movement stations (either perception or vestibular ocular reflex

assessments). Interpupilary distance measurements were recorded with a digital pupilometer for the subjects assigned to the VOR stations. EGG electrodes were applied to the subjects assigned to the gimbaled chair (4 per flight) prior to embarking the aircraft.

Flight Profile

Sustained hyper-G (1.8 Gs) was induced through a series of banked turns in a NASA KC-135 (approximately 3.5o/s turn, with a 56 deg. angle of bank, at 467 knots actual airspeed, resulting in a 2-nautical mile radius). Each hyper-G run lasted 5.5-min. During a hyper-G run, the aircraft maintained a minimum ascent rate to stay out of its own turbulence. Following a hyper-G run, there was a brief repositioning time (average 5 min) during which the plane descended to an appropriate altitude to start the next run. There were a total of three flights, each on a separate day, and each with new subjects. Ideally, each flight was designed to carry 10 subjects (Table 1). Each subject was to participate in four experimental periods, with each experimental period consisting of two successive hyper-G runs (for a total of eight hyper-G runs). During each experimental period, subjects were either at rest or at one of four experimental test stations: G-Excess VOR 1, G-Excess VOR 2, and G-Excess Perception or the Gimbaled Chair. However, during Flight One, only five hyper-G runs were completed, with the first, third and fourth experimental periods consisting of one hyper-G run and the second experimental period consisting of two hyper-G runs. Flight Two was completed as planned. During Flight Three, the last hyper-G run was aborted. Hence, the fourth experimental period of Flight Three consisted of only one hyper-G run. In addition, during Flight One, subject positions one and three were not filled. During Flight Two, all subject positions were filled. During Flight Three, subject position 25 was not filled.

Head Movement Protocols

The Active protocol involved an active head movement protocol (Figure 1) and was performed at each of three different test stations: G-Excess VOR 1, G-Excess VOR 2 and G-Excess Perception. The active head movement protocol consisted of two separate head movement sequences, each being performed during a single hyper-G run of the Active protocol. The order of presentation of sequence A or sequence B was alternated for each experimental period. The Passive protocol involved passive roll movements and was performed at only the gimbaled chair test station . During passive head movements, a subject was secured in a gimbaled chair with a five-point harness. The subject's head was positioned upright in a chair mounted headrest to restrict head movement. During Flight One, a human operator oscillated each subject in the gimbaled chair continuously from 45 deg. left to 45 deg. right at approximately 0.6 Hz for the entire hyper-G period. During Flights Two and Three, the subject was rolled 45deg. left and right in the gimbaled chair, being held in each position for 30 s as follows: upright 30 s, left 30 s, upright 30 s, right 30 s, upright 30 s, left 30 s, etc., continuously for the entire hyper-G period. This change was made due to the difficulty in continually rocking the gimbaled chair under hyper-G, the recording artifact that continuous rocking introduced into the physiological recordings and to simplify the overall protocol by synchronizing the Active and Passive protocols. Subjects not participating in either the Active or Passive protocol rested quietly while sitting or supine in standard aircraft type seating or on the floor of the aircraft (Rest

protocol). Subjects made incidental head movements during the Rest protocol, but were asked to stay seated or supine during each hyper-G period. The informed consent form requested that subjects minimize head movements during the Rest protocol.

RESULTS:

All subjects -- The mean MSHQ score for all subjects was much lower than a population of undergraduates (10 vs. 26; $t[24] = 9.7$, $p<0.05$). This suggests that as a whole, the subjects in our study had a below average susceptibility to motion sickness. This is a logical result as the NASA KC-135 is affectionately known as the "Vomit Comet," and individuals with a strong history of motion sickness tend to avoid being test subjects. In addition, approximately one-third of our subjects were student naval aviators or flight officers; this group tends to be self-selective against motion sickness. Nonetheless, 7 out of the 27 subjects vomited during the flight (26%). Nausea initially increased during the first experimental protocol, but then was fairly stable over the duration of the flight ($F[5/105] = 3.7$, $p < 0.05$). For the six subjects who experienced all of the head movement protocols, there was a significant effect of protocol, with the Active protocol producing the most nausea ($F[4/20] = 2.8$, $p < 0.05$). This effect appeared to hold for the mean nausea scores for all subjects. However, it is important to note that the level of nausea reported in these by protocol analyses is very low. Hence, any conclusions regarding the levels of nausea induced by the various head movement protocols are tentative.

Eight EGG subjects

The mean MSHQ score for those subjects selected for physiological recording was somewhat lower than that found for a group of 191 undergraduate students (18 vs. 26, $t[7] = 4.1$, $p < 0.05$). This suggests that even though subjects who were selected for physiological recording were selected to be the most susceptible to motion sickness, they actually had a motion sickness history slightly lower than average. The Vomiters showed greater total nausea pre-G, during hyper-G and post-G compared to the Nonvomiters ($F[1/5] = 264.9$, $p < 0.05$). In addition, the Vomiters showed an increase in nausea during hyper-G not seen in the Nonvomiters. This is evidenced by a main effect of G period ($F[2/10] = 16.3$, $p < 0.05$) and a vomiting status by G condition interaction ($F[2/10] = 12.9$, $p < 0.05$).

The Vomiters showed consistently less normal 3 cpm across the G-periods compared to the Nonvomiters, a difference that approached statistical significance ($F[1/6] = 4.5$, $p < 0.10$). The Vomiters had slightly greater tachyarrhythmia pre-G, during hyper-G and post-G compared to the Nonvomiters (Fig. 2), a difference that was not statistically significant ($F[1/6] = 3.0$, $p < 0.20$). G period appeared to affect tachyarrhythmia differently by vomiting status (Fig. 2), with the Nonvomiters showing a decrease in tachyarrhythmia post-G not seen in the Vomiters. However, this interaction only approached statistical significant ($F[2/12] = 3.7$, $p < 0.10$).

The Vomiters had significantly more somatic ($F[1/5] = 96.9$, $p < 0.05$), gastrointestinal (GI; $F[1/5] = 184.5$, $p < 0.05$) and emotional distress ($F[1/5] = 11.6$, $p < 0.05$) across the

G conditions compared to the Nonvomiters (all F-values are for main effect of vomiting status). The Nonvomiters showed little change across the G conditions whereas the Vomiters showed a large increase in somatic ($F[2/10] = 9.8$, $p < 0.05$) and GI distress ($F[2/10] = 10.0$, $p < 0.05$), and a small increase in emotional distress ($F[2/10] = 11.0$, $p < 0.05$) during hyper-G (all F-values are for vomiting status by G condition interactions). These increases appear to return to pre-G levels following hyper-G. It is important to note that although the changes in emotional distress are statistically significant, the levels reported by both vomiting status groups are negligible.

G-excess Perception

Reports of visual target movement during onset/offset of hypergravity and following each head movement profile are presently under review.

G-excess VOR

Analysis of video-oculographic data of the subjects' eye movements is under way.

DISCUSSION:

Nausea and Motion Sickness

The level of nausea reported and the number of subjects that vomited confirmed the results seen in previous KC-135 hypergravity flight [Baylor, 1992]. Based on motion sickness history, the subjects in the current study had a lower than average susceptibility to motion sickness. Nonetheless, 26% of the subjects in this study vomited in response to hyper-G. This vomiting cannot be attributed to a Coriolis cross-coupling effect as head-movements in 1-G at similar rotation rates produce little nausea, and no vomiting [Graybiel, 1969]. Further, three of the seven subjects who vomited never moved from their original pre-flight positions before vomiting (they remained in the Rest protocol). This suggests that the experience of hyper-G alone, without provocative head movements, is sufficient to induce nausea. It is likely that the vomiting observed is due to a G-excess effect on the otoliths. This effect appears to be most provocative in the +Gz (head to foot) axis. It was observed that when subjects who were nauseated and/or vomiting moved to a supine position, with the hyper-G then being through the +Gx (chest to back) axis, the nausea and vomiting appeared to subside. This finding is similar to reports from elevator studies, in which subjects who were supine were not as susceptible to motion sickness as subjects who were standing [McNally, 1944]. Although it is hypothesized that the observed nausea and vomiting is due to a G-excess effect on the otoliths, it could also be due to a nonvestibular physiological change (e.g., visceral stretching, kinesthetic or somatosensory). One unlikely nonvestibular explanation is the neck strain caused by the extra G-loading on the neck. It was previously shown that during a rotation of 4.5o/s in a 1-G field, head movements made while wearing a helmet weighted to simulate a 2-G load caused little nausea and no vomiting [Gilson et al, 1973].

It is important to note that prior to being airborne, the passenger compartment of the aircraft was not cooled. This led to very warm temperatures prior to reaching altitude. This heat effect could have confounded results, leading to increased rates of nausea and

vomiting. However, no one vomited prior to the first G run, at which time the aircraft was sufficiently cool. Thus, the heat alone does not appear to account for the increased sickness. Further, nausea did not show a consistent increase with time in flight as one might expect if the effect was due to continued exposure to the unique environment of flying in the NASA KC-135. Rather, nausea was specifically associated with head movement protocol and hyper-G period.

In subjects that were exposed to the various head movement protocols, the Active protocol appeared to evoke the greatest level of nausea. Although the reports of nausea by head movement protocol were low, this finding is supported by anecdotal reports following the experiment in which subjects reported that pitch head movements were most provocative ("moving my head from my lap to the upright position was the most sickening"). This finding is consistent with earlier reports from parabolic flight that pitch head movements were the most provocative in both hypo- and hyper-G [Lackner, 1986, 1987]. In parabolic flight, the hyper-G exposures were brief. The current study extends the finding from parabolic flight, that pitch head movements tend to be the most provocative, to a sustained hyper-G environment. This confirms that the sickening effect of pitch head movements is not a by-product of parabolic flight. It is important to note that the head movement protocol effect found in the current study should be considered tentative. It could be explained by differences in the head movement protocols -- active vs. passive nature. For example, during the Passive protocol, subjects were restrained and their heads confined, whereas during the Active protocol subjects were not restrained at all.

In subjects who vomited in response to hyper-G, the Nausea Profile indicated that the nausea experienced had a dominant GI distress component with a secondary somatic distress component, with only negligible emotional distress. This Nausea Profile is similar to the profile observed from an optokinetic drum stimulus in a 1-G field [Muth, 1996]. The only difference is that subjects in the current study had elevated somatic and GI distress pre-G. This is due to the fact that some subjects had already been exposed to several hyper-G runs before the pre-G measurement corresponding to the EGG recording was taken. However, the levels of nausea reported pre-G and post-G were similar to those reported by a group of subjects considered not susceptible to optokinetic-induced motion sickness [Muth, 1996]

In subjects who vomited during hyper-G, disturbances in the EGG appeared similar to those observed in subjects susceptible to motion sickness induced by an optokinetic drum stimulus [Stern, 1985, 1987]. The subjects who vomited appeared to have less normal 3 cpm activity and greater tachyarrhythmic activity compared to those subjects who did not vomit. Furthermore, subjects who vomited showed a decrease in normal 3 cpm activity during hyper-G not observed in subjects who did not vomit. Again the only difference between these findings and those from the optokinetic drum stimulus is that pre-G, subjects who vomited already had a more disturbed EGG compared to subjects who did not vomit. As with the nausea reports, this is likely due to the fact that some subjects had already been exposed to multiple hyper-G runs before the physiological measurement period. It is important to note that these EGG differences were not statistically significant

and therefore need further verification with a larger number of subjects. Nonetheless, they appear to support the negative relationship between 3 cpm and nausea, and the positive relationship between tachyarrhythmia and nausea.

G-Excess Perception

Initial review of perceptual reports appear consistent with those of Baylor, et al [1992]. Most if not all subjects perceived visual target motion during onset of hypergravity runs. Due to subject motion sickness and/or subjects that did not arrive on time for their flight, we were able to run some subjects more than once through this protocol. These subjects typically reported increased target motion during their second set of runs than they reported on their first runs. This may have been due to an increased familiarity with the disorienting sensations that follow head movements in hypergravity. Further analysis will investigate this possibility as well as document other perceived target motion.

G-Excess VOR

This portion of the experimental setup was the most complex and, as a result, the most problem ridden. The ruggedized mil-spec computer that carried the software to integrate and control the video data acquisition and backup the accelerometer and rate sensor data failed one half hour prior to the start of the first flight. This was likely due to the combination of high temperatures and humidity experienced the previous afternoon (after the test equipment had been installed), along with the rapid cooling provided by the air conditioning system on the ground. Water had condensed on every metal surface in the test area of the aircraft and likely inside the computer (later analysis showed that both the PC mother board and the hard drive had failed). The VCR's were operational throughout the three flights as were the time code inserters that placed accurate time of day on the video in barcode form. In addition to the time, digitized data from the accelerometers and rate sensors was also inserted into the barcode. Therefore, data from the second two flights was recorded despite the failure of the computer. Post flight analysis is still continuing on this data. Additional problems occurred with one of the time code inserters which lost one video signal (VOR station 1, right eye), intermittently at first and then continuously early in the first flight. Lastly, the IR illumination intermittently failed while under G. Post flight testing could not duplicate the failure, but it is assumed that the hypergravity caused an intermittent short or open circuit. The short duration of the illumination drop outs will cause some loss of data, but each run should still be salvageable. The loss of the right eye signal from VOR station 1 precludes analysis of binocular data from subjects tested at that station.

CONCLUSIONS:

In conclusion, sustained hyper-G exposure with negligible angular velocity provokes nausea and vomiting in a significant number of individuals that is likely attributed to a G-excess effect on the otoliths and not a Coriolis cross-coupling effect. The similarity in nausea reports and apparent EGG changes between hyper-G and optokinetic stimulation suggests that the experience of nausea in an altered force environment (hyper-G) is similar to that experienced in a normal force environment (optokinetic stimulation). Hence,

although the stimulus that causes the nausea differs, the end-organ response during cognitive interpretation of nausea appear to be the same.

Control of the thermal environment in the KC-135 proved difficult during this experiment. Two factors resulted in equipment failure: 1) the high heat and humidity in Houston, TX, during the late summer and 2) the blackout curtains that restricted normal airflow in the KC-135 cabin. While the excess heat did not adversely affect the nausea and motion sickness data, it did impact the quality of the data acquired for the G-excess illusion. Initial evaluations of the G-excess illusion data appears to support previous results. Completion of this data analysis should provide further insight into the dynamics of the g-excess illusion.

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PHOTOGRAPHS:

98EO7282 to 98EO7361

VIDEO:

Zero-G Flights week of Aug. 24 to Aug. 27, 1998, PMU: 11/46897, Master: Provided HI-8MM

Videos available from Imagery and Publications Office (BT4), NASA/JSC.

20000 25624

59/52

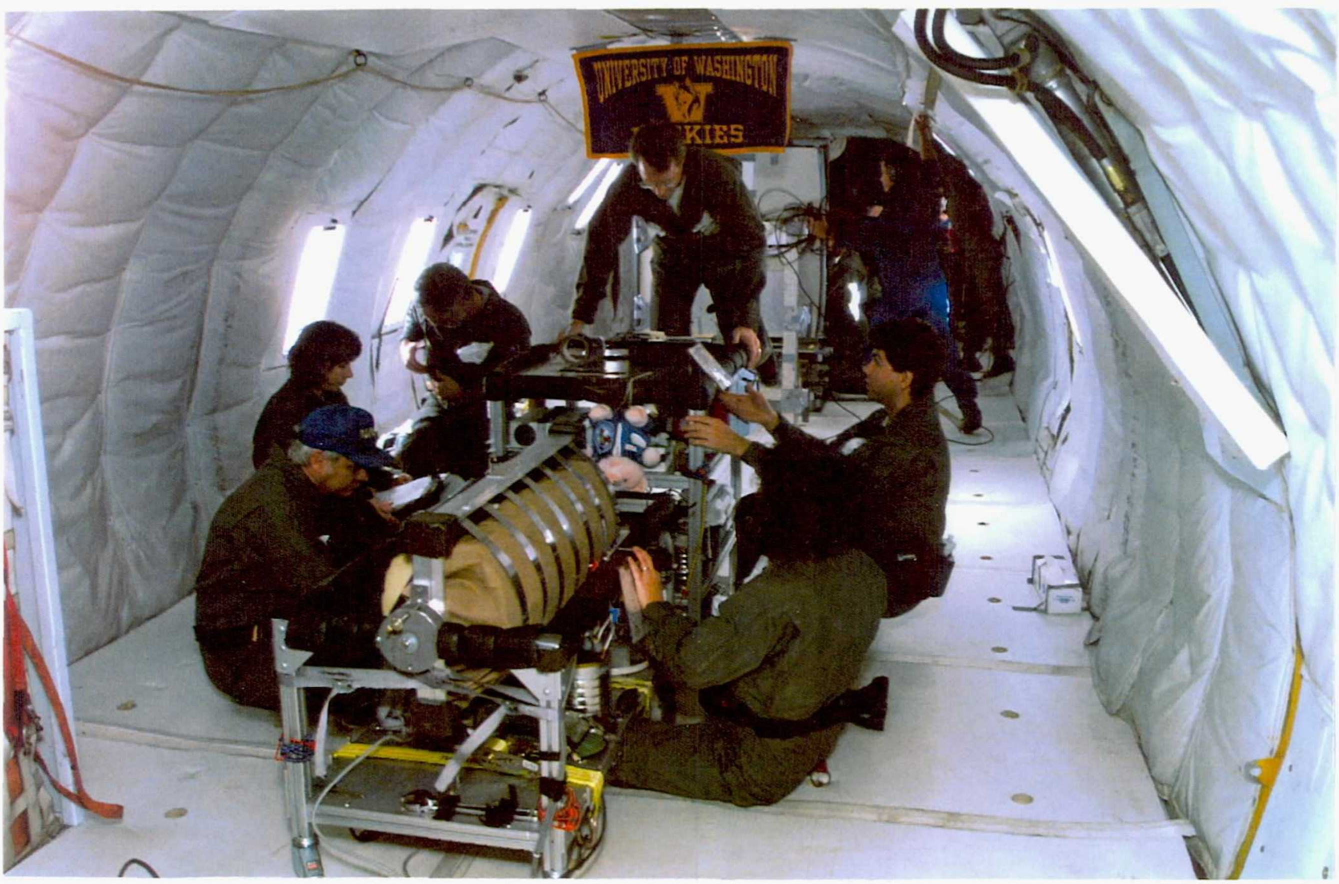
434267

TITLE:
Contribution of Gravity to Lung Blood Flow Heterogeneity

FLIGHT DATES:
October 20-22 and
November 9-13, 1998

PRINCIPAL INVESTIGATORS:
M. Hlastala, University of Washington
H. Thomas Robertson, University of Washington

CO-INVESTIGATORS:
Doan An, University of Washington
Susan Bernard, University of Washington
Myron Chornuk, University of Washington
Robb W. Glenny, University of Washington
Wayne J.E. Lamm, University of Washington
Wiltz W. Wagner, Indiana School of Medicine



NASA Photo: 98EO9321

GOAL:

To obtain a quantitative estimate of the importance of gravity in the distribution of blood flow to the lung.

OBJECTIVE:

Measure the spatial distribution of blood flow to the lungs of anesthetized juvenile pigs during microgravity, 1G and 2G in both prone and supine positions by intravenous injection of different colors of fluorescent microspheres which lodge in pulmonary capillaries.

INTRODUCTION:

The estimation of blood flow distribution in the lung obtained from indirect gas concentration methods on the SLS-1 yielded a very surprising result, in that the distribution of blood flow in the lung did not appear to be substantially altered by weightlessness. The best explanatory model for the distribution of blood flow to the lung prior to those findings had been the three zone model developed by John West, which postulated that the regional flow differences could be satisfactorily explained by the influence of gravity on the low pressure blood flow circuits of the lung.

The measurements obtained by West and colleagues had relatively low spatial resolution. Subsequent investigators using lungs injected with microspheres as flow markers, inflated, and cut into thousands of pieces demonstrated a far greater degree of heterogeneity than would have been predicted from the simple gravitational model. While the gravitational gradient could still be detected by these studies, it was calculated to account for only about 7% of the total flow heterogeneity.

The calculations on experiments conducted at 1G were only indirect evidence of a weaker effect of gravity, however, as the effects of gravity were estimated from the changes measured in blood flow in animals turned from prone to supine position. What was lacking was direct measurement of blood flow distribution at microgravity and at higher G forces in the same animals. The NASA KC-135 aircraft provided the opportunity to directly investigate the effects of microgravity on blood flow distribution on the lungs of anesthetized animals utilizing the high resolution techniques we had developed in our laboratories.

MATERIALS AND METHODS:

Animals

Anesthetized 25 kg juvenile pigs were used for all studies, as they were animals with large enough lungs to permit sampling more than 1,000 pieces, but small enough to readily handle and transport.

Instruments

While the experiment itself required only the intravenous injection of different colored 15 micrometer fluorescent microspheres at specific times during the parabolic flight profiles, a complete system for mechanical ventilation and cardiopulmonary monitoring was required to insure stability of the anesthetized pig during the flight. Continuous measurements were obtained of pulmonary artery, arterial, central venous, and airway pressures. Intermittent measurements of cardiac output and arterial blood gases were obtained throughout the flight.

Procedure

The animal was held in a rotating bed apparatus which permitted turning the animal from prone to supine position without interfering with any of the intravascular monitoring lines or ventilation connections. After beginning the series of parabolic flight profiles, fluorescent microspheres were injected into the central venous line five seconds after microgravity had been attained, with the completion of injection allowing 12 more seconds for the microspheres to lodge within the pulmonary capillaries. Injections were also made at 1.8G and 1.0G in both prone and supine positions during the flight. After return, the animal was sacrificed by overdose of anesthesia, and the lungs were extracted and inflation-dried for later analysis.

RESULTS:

The following data have been compiled from the first two flights. The subsequent flights were different only in that 30% oxygen was administered to the animals throughout the flight to compensate for the moderate altitude induce hypoxemia which had been noted in the previous flights. Cardiac output and systemic arterial pressure remained within normal range throughout all gravitational conditions. The fit of the regional blood flow data to a vertical height model for all measurements made at 1 and 2G was weak, explaining only 5.9% of the total blood flow heterogeneity. Comparing slopes of the vertical height model at 2G and 0G, a steeper slope in the direction of the gravitational gradient was observed at 2G in both prone and supine positions. However comparing 0G and 1G measurements, there were no predictable changes among the small differences in slope gradients in either posture.

DISCUSSION/CONCLUSIONS:

These preliminary findings suggest that in quadrupeds in both prone and supine positions, normal gravitational forces have a minor and inconstant influence on the distribution of blood flow in the lung. The predominant factor determining the distribution of blood flow in the normal lung appears to be the anatomy of the pulmonary vascular system. These results are preliminary, and are based only on the two animals studied in mildly hypoxic conditions. The final six animals were studied on 30% oxygen, and remained normoxic through the flights. Until the flow data can be completed from these studies, we cannot exclude the possibility that our initial findings have been biased by hypoxic pulmonary hypertension, which would overcome a true gravitational gradient.

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PHOTOGRAPHS:

98EO7712 to 98EO7728
98EO8728 to 98EO8732
98EO8886 to 98EO8891
98EO9297 to 98EO9300
98EO9301 to 88EO9309
98EO9317 to 98EO9322
98EO9324 to 98EO9325

VIDEOS:

Zero-G Week of Oct. 19 to Oct. 23, 1998, PMU#:11/47348, Reference Master: provided

Zero-G Flights - Week of 11/09 thru 11/16/98, PMU#:11/47588, Reference Master: 616687

Zero-G Flights - Week of 11/09 thru 11/16/98, PMU#:11/47588, Reference Master: provided

Videos available from Imagery and Publications Office (BT4), NASA/JSC.

20000025625

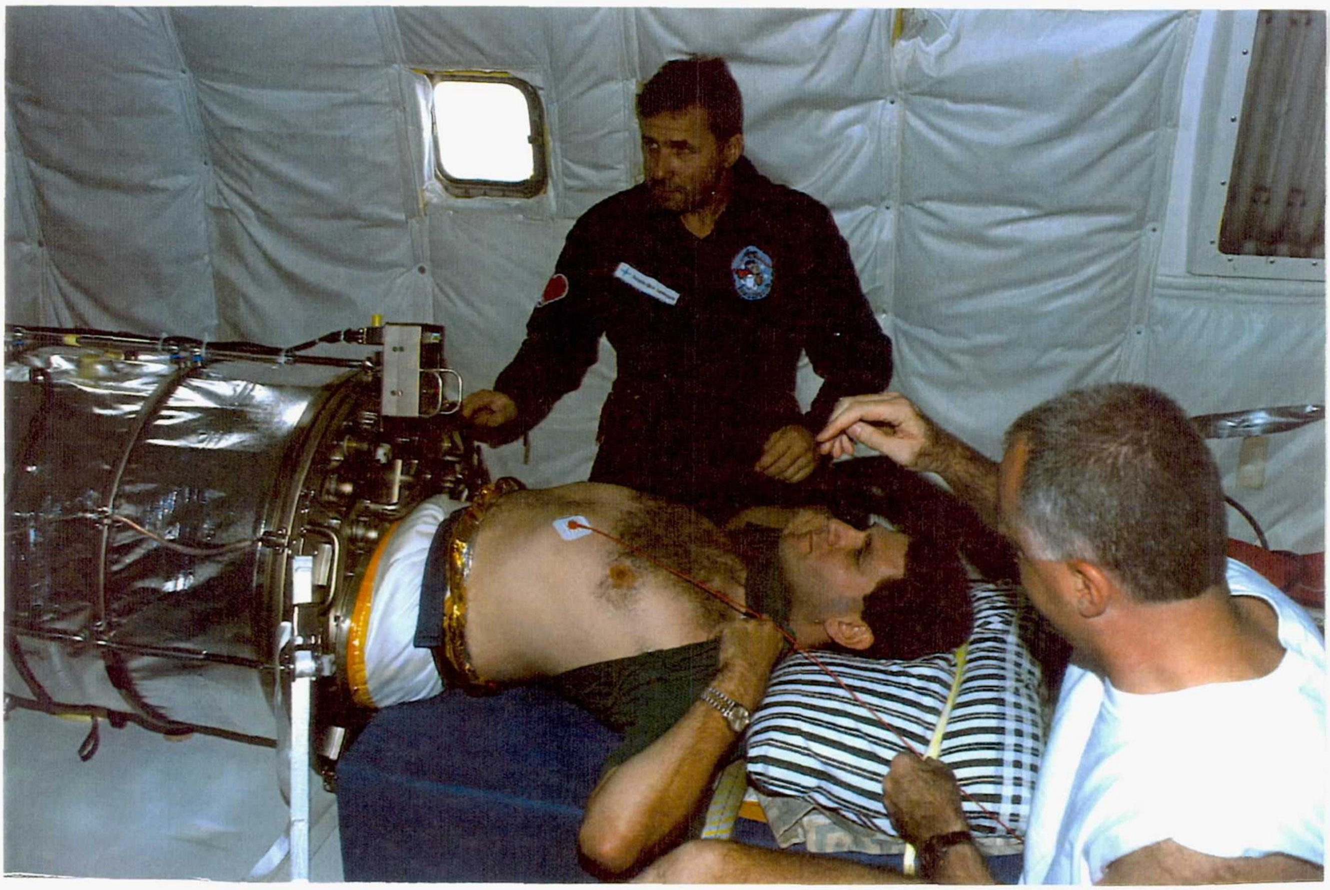
TITLE:
KC-135 Hardware Evaluation of the HRF Lower Body Negative Pressure Device

FLIGHT DATES:
October 22, 1998

510/54

PRINCIPAL INVESTIGATORS:
Kevin Collier, Wyle Life Sciences
Peter Nobmann, Daimler-Benz Aerospace

434270



NASA Photo: 98EO8734

GOAL:

To evaluate design changes made to the hardware post-Critical Design Review, specifically looking at comfort, ability to egress, and zero-g functionality.

OBJECTIVE:

To determine whether the changes made met the requirements for the hardware and whether crew comments were adequately addressed from previous KC-135 and ground-based testing.

INTRODUCTION:

The Lower Body Negative Pressure (LBNP) system is an instrument that encloses the lower body of the test person within a tubular structure and allows the application of a pressure differential inside the system lower than the ambient environment. The pressure differential causes a redistribution of body fluids in the microgravity environment comparable to the fluid distribution that occurs in the upright position in the 1-g environment.

METHODS AND MATERIALS:

Subjects
Two medically qualified male subjects with previous KC-135 and LBNP experience participated in the evaluation of the LBNP system during KC-135 parabolic flight.

Instruments
Human Research Facility LBNP prototype system
accessory gear
safety monitoring equipment

Procedure
The hardware was assembled and setup prior to the flight. The two subjects completed the following:
1) the subject ingressed the bag, secured himself and then the negative pressure was applied. Comfort and ability to use the controls were assessed.
2) A quick "emergency"' egress was performed to see whether egress in less than 30 seconds could be achieved.

These steps were done over the course of several parabolas and then repeated with the other subject in the bag.

RESULTS:

Comfort was satisfactory with only one minor complaint of pressure on the hip. The egress drill was completed in the allotted time. No adverse affects on the subject nor damage to the hardware was noted during the evaluation.

DISCUSSION:

The flight was considered a success. Very favorable results were obtained, indicating that the design was mature and appropriate for a spaceflight environment. All objectives were attained. No significant problems were noted.

CONCLUSION:

The evaluation proved successful. No other flights are planned.

PHOTOGRAPHS:

98EO8733 to 98EO8737

VIDEO:

Zero-G Week of Oct. 19 to Oct. 23, 1998, PMU#:11/47348, Reference Master: provided

Videos available from Imagery and Publications Office (BT4), NASA/JSC.

20000025626

TITLE:
Pulmonary Deposition of Aerosols in Microgravity

511-52

434272

FLIGHT DATES:
October 28 -30, 1998

PRINCIPAL INVESTIGATOR:
G. Kim Prisk, Ph.D., University of California, San Diego

CO-INVESTIGATORS:
Chantal .J. Darquenne, Ph.D., University of California, San Diego
John. B. West, M.D., Ph.D., University of California, San Diego

NASA Photo: 98EO8839

GOAL:

The goal of this study is to perform testing aboard the KC-135 resulting in applications that promote a better understanding of pulmonary diseases related to inhaled particles, in

studying drugs delivered by inhalation, and in understanding the consequence of long-term exposure to respirable aerosols in long duration space flight.

OBJECTIVE:

This study was designed to determine the total deposition of aerosols in the human lung in microgravity (μG), in normal gravity (1G) and in hypergravity (~1.6G); and to chart the deposition and dispersion of aerosols (inhaled boli of 1 micron particles) as a function of the penetration depth into the lung at μG, 1G and ~1.6G.

INTRODUCTION:

Respired airborne particles (aerosols) are deposited at different sites in the respiratory tract depending on their size. There are three primary causes of intrapulmonary deposition. Impaction results in the removal of the larger (> 5 micron) particles in the upper airways, sedimentation mainly affects the medium sized particles (0.5 - 2 microns), while the smallest particles (< 0.1 micron) are subject to the effects of Brownian motions, and are deposited on the airways and alveolar walls primarily by diffusion (Beeckmans, 1965; Davies and Muir, 1966; Muir, 1967a).

Of these three mechanisms, sedimentation is a gravitational process, and is therefore expected to be altered in the μG environment (Beeckmans, 1966; Muir, 1967b). However the fate of these medium sized aerosols in μG is unknown, and theoretical calculations give somewhat conflicting results.

In the spacecraft environment, the potential for significant airborne particle loads is high, since the environment in closed, and no sedimentation occurs. Thus particles remain in the air until removed by active filtration, and this process is energy intensive. Preliminary measurements in the Shuttle air environment have shown a substantial increase in microbial counts during missions (Henney et al., 1984; James, 1992), and a large variety of airborne particles including hair, food, paint chips, and synthetic fibers have been found. Particulate concentration studies have been shown to be raised levels in some flights (Liu et al.,1992). Early shuttle flights provided anecdotal reports of "brown clouds" in the vicinity of the waste containment system, and while this has been fixed, there exists considerable potential for the presence of contaminated aerosol in the spacecraft environment.

It is therefore of considerable interest to determine the fate of inhaled aerosols in an environment that offers altered deposition, and a potentially large airborne particulate load. If alterations in the site of particulate deposition occur, then there may well be long-term health implications of such alterations, especially as longer and longer missions are proposed, and as these missions are likely to occur in environments such as the Mir Station that are potentially less well controlled than the Space Shuttle cabin.

To date, only one study of total lung deposition has been made in the µG environment. Hoffman and Billingham (1975) showed that the deposition of 2.0 micron particles was reduced during short period of microgravity on a NASA LearJet. As a consequence, these particles may well have penetrated deeper into the lung, but this was not directly measured.

The total deposition of aerosol in the lung may be measured by steady breathing at constant tidal volume and frequency from a reservoir in which monodisperse particles have been dispersed (Davies et al., 1972; Heyder et al., 1973; Heyder et al., 1986). Total deposition is determined by recording continuously the aerosol concentration and flow rate at the mouth both during inspiration and expiration. It seems likely that such a measurement would be suitable to carefully study aerosol deposition in short periods of weightlessness.

More recently, the aerosol bolus technique has been developed as a means of charting the behavior of the airways at different depths within the lung (Heyder, 1983). In this method small (approximately 30 ml) boli of aerosol are inhaled at specific points in the breath, and the subsequent exhalation of the aerosol is then examined. In 1-G, by calculating the loss of aerosol from the bolus, the effective airway diameter may then be determined, as the loss of the (typically 1.0 micron) particles is via sedimentation (Heyder, 1983). The inspired bolus can be "positioned" at different points in the inspired breath, allowing for different penetration depths into the lung, and hence allowing probing of different areas of the respiratory tract.

More importantly for these proposed studies, the convective mixing within the respiratory tract can be estimated using aerosol boli (Heyder et al., 1988). By measuring the axial dispersion of the bolus (the width of the aerosol bolus measured as a function of exhaled volume), the degree of which the aerosol disperses along the airways can be determined. The degree of dispersion increases as the penetration depth of the inspired bolus is increased, and at penetration volumes of approximately 600 ml, it appears that aerosol begins to reach the alveoli. Both the dispersion (the width of the exhaled bolus) and the effective depth (the mode of the exhaled bolus) provide information on convective mixing in the lung. For example, inpatients with cystic fibrosis a significant increase in both of these indices indicate a narrowing of the airways (Anderson et al., 1989).

Since aerosols of 1.0 micron are not significantly affected by diffusion, their use also allows a direct probe into convective gas mixing in the lung. We know that overall convective inhomogeneity is reduced in µG (Guy et al., 1994) although it is clearly not absent (Prisk et al., 1994). Thus, aerosol boli provide a probe into changes in regional convective mixing in µG without the confounding effects of diffusion that is always present with gases.

In the present study, we will perform tests consisting in steady breathing of aerosol spanning the range 0.5 to 5 microns on normal subjects during short periods of µG provided by parabolic flight profiles aboard the NASA KC-135 research aircraft. This will

allow us to determine total lung deposition of aerosols in μG. Of particular interest is the behavior of particles of approximately 1 micron in size, those particles which are known to be primarily removed by sedimentation, a gravitational process. The comparison to deposition at 1G will help to elucidate the impact of gravitational sedimentation upon deposition processes.

Using inhaled boli of 0.5, 1.0 and 2.0 micron aerosols, we will chart the deposition and dispersion of these aerosols as a function of penetration depth into the lung. In doing this, changes in aerosol dispersion and the regions of deposition in μG compared to 1G environment will be brought to light.

METHODS AND MATERIALS:

Subjects

The subjects were recruited on a voluntary basis among the employees of the Department of Medicine of the University of California at San Diego and employees from the Johnson Space Center. All subjects passed the required Air Force Class III Flight Physical exam. A total of 4 subjects participated in this study.

Procedure

In the first protocol designed to determine the total lung deposition of aerosols, the subject breathes monodisperse aerosol from a reservoir at a constant tidal volume and frequency over a period of about 5 minutes. In the second protocol focusing on aerosol deposition and dispersion at different depth within the lung, starting from residual volume (RV), the subject takes an inspiration of pure air at a constant flow rate (~0.4 l/s) followed by a breath-hold varying between 0 and 10 sec before the subject exhaled to RV at the same flow rate of ~0.4 l/s. During the test inspiration, a bolus of approximately 80 ml of aerosol is delivered at a selectable volume. During both protocols, the aerosol concentration at the mouth, the flow rate, the barometric pressure and the gravity level are continuously recorded on a PC (IBM ThinkPad 360 CSE) via an A/D board (multi function DAQCard-700).

During the earlier KC-135 flight (week of September 10, 1996), the total deposition was measured on 4 subjects for 0.5, 1, 2 and 3 microns at μG, 1G and ~1.6G. The four other weeks were dedicated to protocol 2. Regional aerosol deposition and dispersion were measured on the same 4 subjects. The following table summarizes the tests that have been performed.

Week of	Particle size (micron)	Penetration volume (ml)	Breath-hold (sec)
March 1997	1	150, 300, 500, 800	0
July 1997	1	500, 800, 1200, 1500	0
	0.5	150,500, 800, 1200, 1500	0
August 1997	2	150, 300, 500, 800,	0

	1	1200 150, 500	3, 5
October 1998	1	300, 1200	10

The experiments performed in October 1998 slightly differed from the previous bolus tests in that small identical flow reversals were imposed during the 10 seconds breath-hold. Each flow reversal consisted in a small inspiratory maneuver immediately followed by a small expiratory maneuver resulting in no overall change in lung volume. These experiments were performed to study the effect of the non-reversibility of the flow on aerosol dispersion in the lung.

RESULTS AND DISCUSSION:

Data from the week of September 10, 1996 have been completely analyzed and compared to predictions from a numerical model. They are the first results of different gravity levels on the deposition of particles of various sizes in the human lung. As expected, intrapulmonary deposition of particles was increased at ~1.6G and reduced in μG compared to deposition at 1G since sedimentation, which is a mechanism of aerosol deposition, is a gravitationally dependent process.

The data were compared with the results of a one-dimensional model simulating the transport and deposition of aerosols in the human lung (Darquenne and Paiva, 1994). Significant and potentially important discrepancies were found between experiments and numerical results. Specifically, in the μG environment, when deposition due to sedimentation was necessarily zero, total deposition of the smallest particles (0.5 and 1.0 micron) was significantly greater than that predicted by the model. However, for the larger particles (2 and 3 microns), the model predictions were quite accurate. Since impaction is a deposition mechanism that is negligible in these very small particles and sedimentation is absent in μG, the extra deposition observed must occurred through enhanced diffusion. It is likely that this enhanced diffusion is a result of the previously unaccounted for non-reversibility of flow in the alveolar regions of the lung. These results have been published in the Journal of Applied Physiology (Darquenne et al., 1997)

Measurements of regional deposition and dispersion of inhaled bolus of 0.5, 1 and 2 micron particles performed during the weeks of March 1997, July 1997 and August 1997 have also been analyzed. At shallow penetration volumes of 200 and 400 ml, deposition of 1 μm particles was not different between gravity levels. In contrast, at larger penetration volumes (> 600ml), when we would expect the aerosol bolus to reach the alveolar region of the lung, deposition was strongly dependent on the gravity level with the largest deposition occurring for the largest gravity level. Based on the data, it, however, looks as if the deposition seen in shallow breaths in microgravity was in fact not different from that seen in normal gravity. This result is consistent with the observation made in the total deposition study where deposition was unexpectedly higher in microgravity than we would have expected based on the normal and hypergravity data. These data were compared to those obtained with 0.5 and 2 μm. In 1G, there was a clear increase in dispersion with

increasing particle size. This result is consistent with the concept that dispersion is a result of the crossing of streamlines, and since the larger particles sediment more readily, they have a higher dispersion. In μG, dispersion was independent of particle size over the range studied, suggesting that the effect of the other intrinsic motions (diffusion, impaction) was sufficiently small that it could be ignored. Importantly, over the range of penetration volumes studied, dispersion continued to increase with increasing penetration volume in μG, suggesting the continued presence of convective ventilatory inhomogeneity in the early generations of the acinar region. A paper describing the results of the 1 μm bolus inhalations has been published in the Journal of Applied Physiology. (Darquenne et al., 1998a). Another paper comparing the results between the different particle sizes has been submitted to the Journal of Applied Physiology (Darquenne et al., 1998b).

Data from the flight week of October 1998 are still under analysis and will be discussed later.

CONCLUSIONS:

The goal of this study is to determine the total deposition of aerosols in the human lung and the deposition and dispersion of these aerosols as a function of the penetration depth within the lung. These experiments have been realized in μG, 1G and 1.6G. Five weeks of KC flights have been performed. In the first one (September 10, 1996), a complete set of total deposition data has been successfully collected at the different gravity levels. The data were obtained from four subjects with four different particle sizes. The data have been completely analyzed and they have been discussed in a paper that has been published in the Journal of Applied Physiology. During the next three weeks of flight (March 11, 1997, July 1, 1997 and August 12, 1997), bolus tests have been performed on the same four subjects at penetration volumes ranging between 150 and 1500 ml using 0.5, 1 and 2 micron particles. These data have also been analyzed and discussed in two papers. One has been published in the Journal of Applied Physiology (Darquenne et al., 1998a) and the other one has been submitted to the same journal (Darquenne et al., 1998b). During the last week of flight (October 28, 1998), slightly different bolus experiments have been performed as small identical flow reversals were imposed during the 10 seconds breath-hold to study the effect of the non-reversibility of the flow on aerosol dispersion in the lung. These data are still under analysis.

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PHOTOGRAPHS:

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VIDEO:

Zero-G Week of October 26-30, 1998, PMU#:47410, Reference Master: provided

Videos available from Imagery and Publications Office (BT4), NASA/JSC.

20000025627

TITLE:
Head Direction Cell Activity under Microgravity Conditions

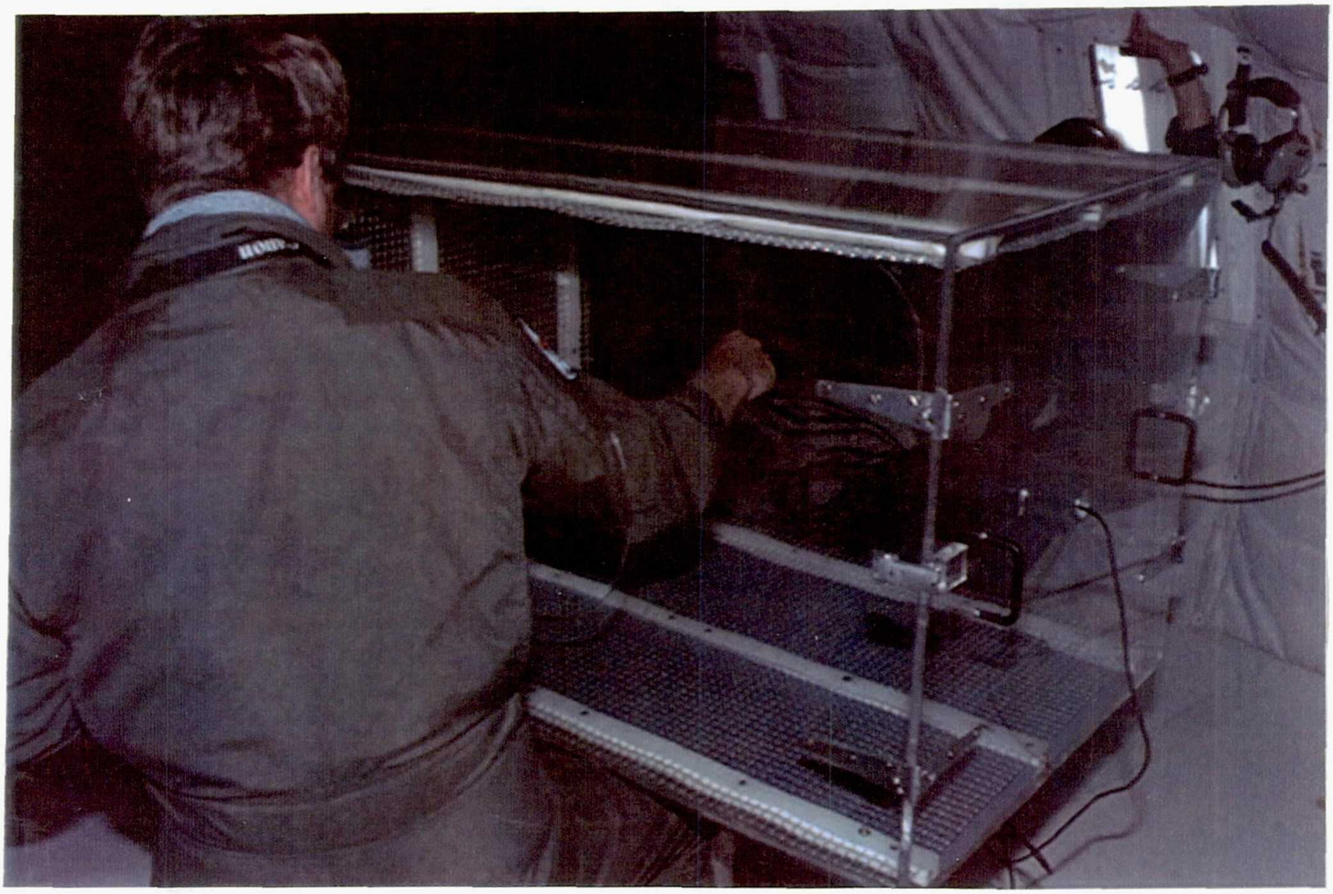
FLIGHT DATES:
October 28-30, 1998

5/2/53

PRINCIPAL INVESTIGATOR:
Jeffrey S. Taube, Ph.D.

4/34275

CO-INVESTIGATORS:
Charles M. Oman, Ph.D.
Robert W. Stackman, Ph.D.



NASA Photo: 98EO8765

GOAL:

To understand the neurobiology underlying visual reorientation illusions and the etiology of motion sickness.

OBJECTIVE:

The long-term objectives of the proposed research are to improve our understanding of how spatial orientation information is processed in the vertebrate brain. Specifically, what are the underlying physiological and cognitive mechanisms which normally support an animal's sense of direction and enable it to orient and navigate within a three-dimensional environment? Previous studies in rat hippocampus, subicular complex, and thalamus have identified two classes of exocentric spatial cells in the brain. One type discharges whenever the animal is in a specific location ("place" cells)(Muller, 1996), while the second ("head direction" cells) discharge as a function of the animal's head direction in the earth's horizontal plane, independent of the animal's behavior and location (Taube et al., 1990; Taube, 1998). Based on well established ground-based experimental paradigms, we propose a series of rodent electrophysiological experiments to characterize the behavior of head direction cells in freely moving animals in various non-gravity orientations. Because astronauts frequently experience spatial disorientation during space flights, it is important to understand the underlying neurophysiological mechanisms contributing to spatial orientation in order to eventually develop appropriate countermeasures. The experiments will be performed aboard the KC-135 aircraft; this aircraft flies parabolic flights in order to simulate the effects of micro-gravity.

INTRODUCTION/METHODS AND MATERIALS:

Rats moved around a three-dimensional 2'x2'x3' cage by climbing on a metal mesh attached to the floor, wall, and ceiling. Once trained, the rats underwent surgery (at the PI's institution) and had an array of electrodes implanted into the anterior dorsal thalamus. Following surgical recovery they were screened daily for the presence of head direction cells. Rats that contained head direction cells were flown and tested aboard the KC-135 aircraft during periods of simulated 0-g. During periods of 0-g the rats were coaxed and hand placed onto different planes of the test apparatus. Cell firing was recorded and the rat's position monitored and videotaped with a video camcorder. Following completion of the experiment, rats were returned to Dartmouth College for further experimentation.

RESULTS:

1) Head direction cells continued to show directional-specific firing under conditions of both 0 g and 1.8 g.
2) When the rat was on the wall in 0 g conditions head direction cell discharge was similar to that observed under 1 g conditions.
3) When the rat was on the ceiling in 0 g conditions, two patterns of firing was observed - a) cell fired at somewhat higher firing rate, but was not strongly directionally tuned. Thus, cell firing was characterized as sporadic, with no definitive firing in one directional heading; b) the cell reversed its preferred firing direction by 180°. We suspect that on these occasions the rat was experiencing a visual reorientation illusion.

DISCUSSION/CONCLUSIONS:

These results indicate that the generation of head direction cell activity is not dependent on the presence of 1 g. However, the presence of gravity, in combination with visual cues, influences the preferred firing orientation of these cells. Furthermore, the change in preferred orientation in the firing of these cells when the rat was on the ceiling may reflect the underlying neural basis for visual reorientation illusions experienced by astronauts in 0-g.

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PHOTOGRAPHS:

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VIDEO:

Zero-G Week of October 26 - 30, 1998, PMU#:47410, Reference Master: provided

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2000025628

TITLE:
Evaluation of the Hydrodynamic Focusing Bioreactor (HDFB) and the Centrifugal Absorption Cartridge System (CACS) Performance under Micro G

FLIGHT DATES:
October 29-30, 1998

5/3/35

PRINCIPAL INVESTIGATORS:
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434278

CO-INVESTIGATORS:
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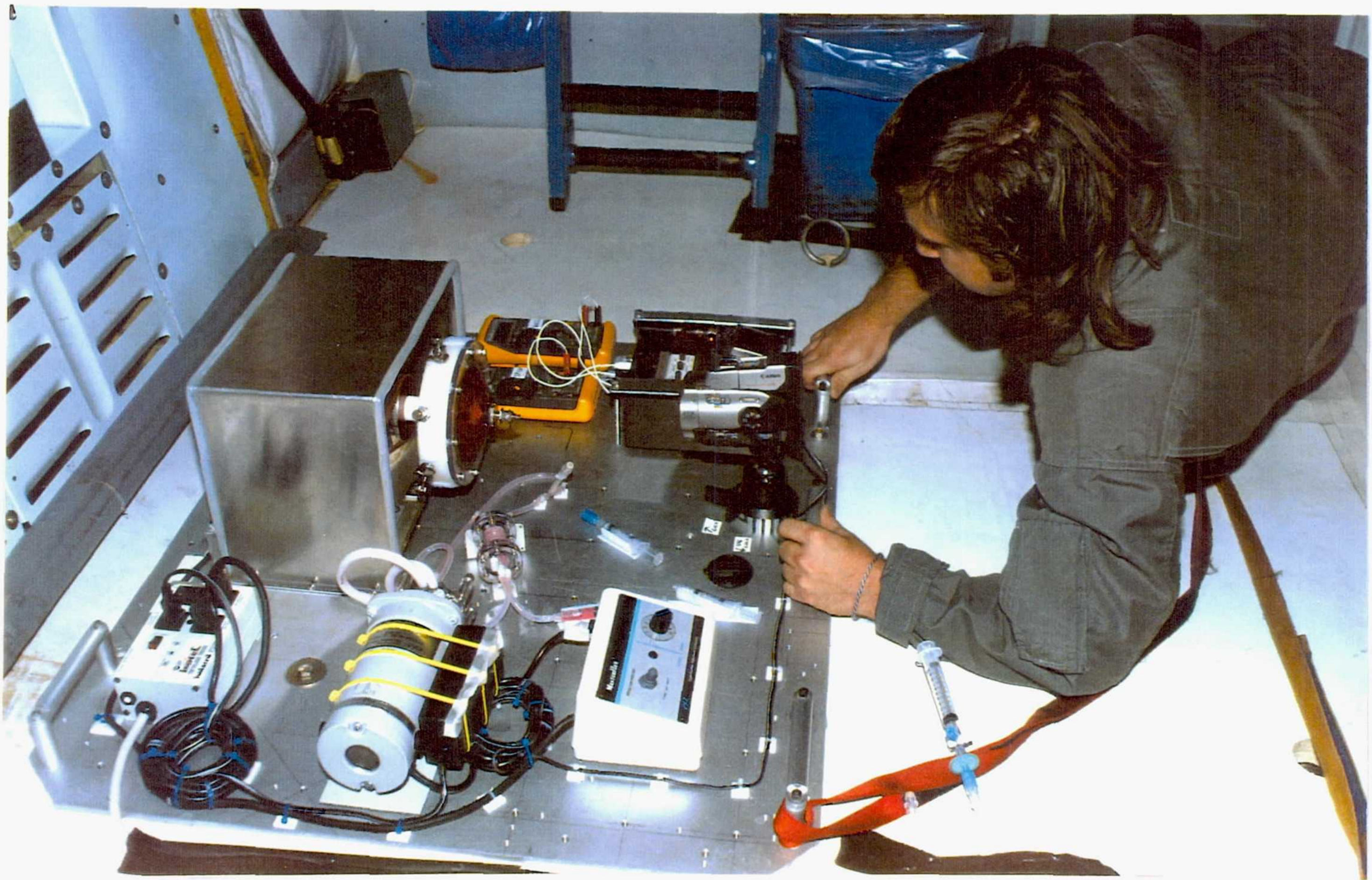

NASA Photo: 98EO8872

GOAL:

To evaluate the Hydrodynamic Focusing Bioreactor (HDFB) aboard the KC-135 during microgravity (micro G).

OBJECTIVE:

The Advanced Technology Development Office at the Johnson Space Center has developed the HDFB to support the Biotechnology Cell Science Program. The hardware evaluation under 1G was very promising, which led to the need for testing aboard the KC-135.

INTRODUCTION:

The HDFB technology is designed to provide a flow field with nearly uniform shear force throughout the vessel, which can provide the desired low shear force spatial environment to suspend three-dimensional cell aggregates while providing optimum mass transfer. The reactor vessel consists of a dome-shaped cell culture vessel, a viscous spinner, an access port, and a rotating base. The domed vessel face has a radius of R_o and rotates at ω_o rpm, while the internal viscous spinner has a radius of R_i and rotates at ω_i rpm. The culture vessel is completely filled with cell culture medium into which three-dimensional cellular structures are introduced. The HDFB domed vessel and spinner were driven by two independent step motors.

METHODS AND MATERIALS:

The HDFB KC-135 tests were performed on October 29 and 30. The experiment hardware was mounted on a 3' x 2.5' aluminum mounting base (pallet). The test performed on the HDFB was to observe the device's "focusing" capability and the ability of the vessel to localize and control air bubbles within the reactor vessel for easy removal. The test was also to observe co-location of the cells within the reactor for improved cellular communication and tissue formation. This is referred to as the "hydrodynamic focusing effect". The HDFB was documented by still photography and video photography during the micro G portion of each parabola. The vessel was preloaded with the simulated media particles before the flight. During the flight HDFB stepper motors were adjusted at different speeds while the cameras recorded particle and bubble movement.

The test performed on the CACS was to observe the device's gas bubble separation capability. The CACS circulation pump was run at several predetermined speeds. As air was introduced into the fluid loop, the CACS was documented by still photography and video photography during the micro G portion of each parabola.

RESULTS/DISCUSSION:

Operation of the motors, motor controllers and frequency output meters were nominal. There was no leakage of experiment fluid or any hazardous condition resulting from the use of required syringes. The tests were successful; we were able to visualize and record the focusing effect of the HDFB under micro G, and also the cell aggregate simulators and air bubbles. The recorded video and audio data are currently under review.

PHOTOGRAPHS:

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VIDEO:

Zero-G Week of October 26 - 30, 1998, PMU#:47410, Reference Master: provided

Videos available from Imagery and Publications Office (BT4), NASA/JSC.

20000025629

TITLE:
Evaluation of Factors Affecting Powdered Drug Reconstitution in Microgravity

FLIGHT DATES:
November 12-13, 1998

514/29

PRINCIPLE INVESTIGATORS:
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Smith Johnston, M.D., NASA/Johnson Space Center

434283

CO-INVESTIGATORS:
Tom Marshburn, M.D., NASA/Johnson Space Center

NASA Photo: 98EO9314

GOAL:

To study the factors affecting drug reconstitution in zero-g, specifically: drug type (drug solubility), container size and shape, amount of diluent, amount of gas in container after diluent infusion, and mixing method.

OBJECTIVE:

To confirm that powdered drug reconstitution can be performed adequately in 0-G using standard clinical and pharmacological apparatus and to evaluate the factors that may affect the dissolution process.

INTRODUCTION:

Owing to the high cost of transporting mass into space, and the small volume available for equipment in the Space Shuttle Orbiter and the International Space Station, refrigeration space is extremely limited. For this reason, there exists strong motivation for transporting certain drugs in powdered form so that they do not require refrigeration. When needed, the powdered drug will be mixed with saline to obtain a liquid form that may be injected intravenously. While this is a relatively simple task in a 1-G environment, there are some diffculties that may be encountered in 0-G. In non-accelerated spaceflight, gravitational and inertial forces are eliminated allowing other smaller forces, such as capillary forces and surface tension, to dominate the behavior of fluids [1]. For instance, water slowly ejected from a straw will tend to form a sphere, while fluid in a container will tend to wet the inside surface forming a highly rounded meniscus. Initial attempts at mixing powdered drugs with saline in microgravity have shown a tendency toward forming foamy emulsions instead of the desired homogeneous solution. The predominance of adhesive forces between the drug particles and the interface tensions at the gas/liquid and solid/liquid interfaces drastically reduce the rate of deaggregation of the drug powder and also reduce the rate of absorption of saline by the powder mass. In addition, the capillary forces cause the saline to wet the inside of the container, thus trapping air bubbles within the liquid. The rate of dissolution of a powder drug is directly proportional to the amount of surface area of the solid that is exposed to liquid solvent [2]. The surface area of drug that is in contact with the liquid is greatly reduced in microgravity and, as a result, the dissolution rate is reduced as well.

Studies on drug dissolution in a 1-G environment lend insight into factors that may be important in space. For instance, Elworthy and Lipscomb (1969) found that dissolution rate depended on both stirring rate and the use of a surfactant [3]. Murthy and Samyn (1977) found that the poor dissolution in shear mixing of drugs containing magnesium stearate as a lubricant was due to the formation of a hydrophobic film around the powder mass that prevented wetting and deaggregation [4]. Most recently, de Almeida et al. (1997) have proposed that an alternative methodology should be applied to polydispersive powdered drugs [5].

The KC-135 research described here was aimed at evaluating the extent to which it is possible to perform drug reconstitution in the weightlessness of parabolic flight using standard pharmacological supplies. The experiment included a parametric assessment of possible factors affecting the reconstitution process. The specific questions that we wished to answer were:

1) Is it possible to reconstitute powdered drugs in weightlessness using standard pharmacological equipment?
2) What are the differences between drug reconstitution in a 1-G and a 0-G environment?
3) What techniques of mixing the drug powder and diluent are more successful?
4) What physical and chemical factors play a role in determining the success of mixing and dissolution?

5) Is it necessary to employ crewmember and equipment restraints during the reconstitution process?

METHODS AND MATERIALS:

Equipment

1) Experiment supplies container:
   Rubbermaid container, measuring 15 cm x 28 cm x 48 cm, with detachable lid.
2) Sharps container
3) Syringes (2 x 20 cc + 2 x 10 cc)
4) Syringe needles (20 x 18 gauge)
5) Drug vials:
   - Rocephin (Ceftriaxone)(6 x 1 g) — cephalosporin antibiotic
   - Timentin (Ticarcillin) (6 x 3.1 g) — semisynthetic antibiotic
   - Diamox (Acetazolamide) (6 x 500 mg) — diuretic (carbonic anhydrase inhibitor)
   - Erythromycin Lactobionate (6 x 1 g) — macrolide antibiotic
   - Solu-Medrol (Methylprednisolone) (3 x 500 mg + 3 x 1 g Act-O-Vials) — anti-inflammatory steroid
6) Saline bags (2 x 500 mL, 2 x 250 mL)
7) Medical chucks (1 per flight)
8) Primitive manual centrifuge (wire-frame device with handle at one end and indentation for attaching vial at opposite end)

Procedure
Prior to flight, one vial of each drug was reconstituted in 1-G to establish a baseline. The reconstitution procedure was performed as follows: The required amount of diluent (normal saline) was withdrawn from an IV saline bag ("supply" bag) and injected into the drug vial using a syringe and needle. The vial was then shaken to achieve mixing of the powder and diluent. After a few seconds, the vial was inverted and a portion of the drug solution was withdrawn and injected into another IV saline bag ("target" bag). In the case of Solu-Medrol, an Act-O-Vial system was used, in which the vial is divided up into two compartments separated by a rubber stopper, a lower compartment containing the drug powder, and an upper compartment containing the diluent. The plastic cap and rubber stopper in the top of the vial are pushed down, displacing the diluent and forcing out the lower stopper so that the diluent can mix with the drug powder. After shaking the vial and waiting a few seconds to ensure adequate mixing, the vial was inverted and the drug solution drawn off with a needle and syringe and injected into the target saline bag. In each case, an attempt was made to perform the actions of injection of diluent, mixing, withdrawal, and injection into the saline bag, in under a minute so as to simulate the time constraints anticipated during flight (about 30 seconds per parabola). The entire process for each drug was captured on video.

The inflight experimental setup may be described as follows: The drug vials, syringes and needles were secured to the sides of the Rubbermaid container using velcro. The two

saline bags ("supply" and "target"), were secured to the bottom of the container using velcro. The container itself was secured to the aircraft floor using duct tape. The lid of the Rubbermaid container was inverted and secured to the floor alongside the container using duct tape. The inside surface of the lid had attached velcro strips for securing the various items in use during experiment execution (two saline bags, drug vial, and syringe with needle) and was used as a work space, while the container served as storage space. A medical chuck was taped alongside the lid to act as a catch area to absorb fluid escaping from the vials due to pressurization. The sharps container was taped to the floor on the right side of the investigator, and a clipboard with checklists was taped to the floor in front of the lid. A video camera was mounted on a stand in front of the setup and zoomed in to the work space (lid) to get a close-up view of each vial during mixing. Lower body restraints were used throughout the experiment to keep the investigator in close proximity to the equipment and to ensure safety during manipulation of exposed syringe needles. To achieve the desired restraint, the investigator knelt down on a foam seat bottom (for comfort during 2-G pull-ups) and was secured to the floor by two sets of straps, one crossing his lower legs close to his knees, and the other near his ankles.

The inflight procedure was executed as follows: For the drugs that required the diluent to be injected into the vial, the syringe was charged with the required amount of saline (9.6 mL for Rocephin, 13 mL for Timentin, 20 mL for Erythromycin, and 5+ mL for Diamox) during a single parabola. During the following parabola, the diluent was injected into the vial, mixed with the powdered drug, a portion of the solution withdrawn by syringe and then injected into the target saline bag. In the case of the Act-O-Vial drug containers, since the diluent was already in the vial, the entire process was performed in a single parabola. The diluent was brought into contact with the powdered drug by pushing in on the top plunger and then shaking or swinging the vial to move the diluent into the lower chamber. After mixing, attempts were made to move the solution back into the upper compartment for extraction be needle and syringe and subsequent injection into the target saline bag. The following mixing techniques were performed on all drug vials (one technique per parabola).

1. *Shaking* (usually a reciprocating motion parallel to the symmetry axis of the vial)
2. *Swirling* (swinging the vial in a conical path by motion from the wrist and elbow joints; radius ~ 45 cm, speed ~ 60 rpm)
3. *Swinging* (moving the vial through a larger circular arc by motion from the shoulder with the arm kept straight; radius ~ 70 cm; speed ~ 60 rpm)
4. *Centrifuging* (vial clipped to the end of the wire-frame device and swung in circular arc; radius ~ 50 cm; speed ~ 60 - 120 rpm)

After use, the drug vials were returned to the storage container, and discarded needles were capped and placed in the Sharp-Trap.

RESULTS:

Ground-based experiments revealed the range of solubilities amongst the drugs. Rocephin was extremely soluble, while Diamox and Solu-Medrol showed a high degree of solubility.

All three of these drugs required little mixing (by shaking) before an adequately homogeneous solution was obtained. Timentin showed only moderate solubility and required relatively vigorous shaking in order to deaglommerate the powder. The time required for dissolution was about twice that for Rocephin. Mixing and dissolution were unsuccessful for Erythromycin. The powder and saline diluent quickly formed a foam and it was not possible to extract a viable quantity of homogeneous liquid. The Act-O-Vial system proved to be very convenient for ground-based reconstitution. The top plunger was easily depressed causing the diluent to force out the separating stopper, thereafter the diluent immediately dropped down into the lower compartment containing the drug powder which it readily mixed with and dissolved. Eliminating the need for filling a syringe with the required amount of diluent and injecting it into the vial, proved to be a significant time-saver. During these ground based trials, it was observed that the regular vials achieved a significant amount of pressurization, particularly with the smaller vials, such that the needle and syringe could not be left with the needle inserted through the rubber stopper, unless the syringe was held in place. (It was hoped that the syringe could be left in place with the needle inserted through the stopper to save time during subsequent reconstitution and drug solution withdrawal in parabolic flight, given the short amount of time per parabola).

A summary of descriptive data and results from in-flight experimentation is shown in Table 1.

Table 1. Description of vials and mixing and extraction results. Note that values in parentheses refer to the fraction of trials that were successful.

Drug Type	Drug Amt. (g)	Vial Type	Vial Vol. (mL)	Diluent Vol. (mL)	Gas: liquid ratio†	Solu-bility	Best Mixing Method	Success-fully mixed	Success-fully withdrawn
Rocephin	1.0	Regular	14.5	9.6	0.5	High	Centrifuge	Y (5/5)	Y (5/5)
Timentin	3.1	Regular	59.0	13.0	3.5	Medium	Centrifuge	Y (4/5)	N (2/5)
Diamox	0.5	Regular	14.9	5.0	2.0	High	Centrifuge	Y (4/4)	Y (4/4)
Erythro-mycin	1.0	Regular	~30	20.0	~0.5	Low	none	N (0/5)	N (0/5)
Solu-Medrol	0.5	Act-O-Vial	22.0	4.0	4.5	High	Swirling*	Y (2/2)	N (0/2)
Solu-Medrol	1.0	Act-O-Vial	25.0	8.0	2.1	High	Swirling*	Y (2/2)	N (0/2)

*Centrifuging not attempted for these vials

†Assumed that powder does not add to volume of solution, i.e., vol. of gas = vol. of vial - vol. of diluent.

In general, the best mixing method appeared to be full-length arm swings or centrifuging using the wire-frame swing-arm. Swirling using forearm motions was also reasonably effective. Shaking tended to form a foamy emulsion resulting in difficulty with extraction of the drug solution. A higher gas:liquid ratio tended to improve mixing but made solution withdrawal more difficult. Rocephin demonstrated the highest degree of solubility and was easily reconstituted, withdrawn, and injected into the target saline bag within a single parabola. Diamox followed closely behind Rocephin in terms of ease of reconstitution and

extraction. Timentin was somewhat more difficult to reconstitute, given its lower solubility, and it was also more difficult to withdraw some of the resulting solution due to the higher gas:liquid ratio. Erythromycin proved to be just as insoluble in 0-G as it was in 1-G. Mixing was unsuccessful, and it was not possible to extract a homogeneous solution following attempted reconstitution.

The Act-O-Vial system proved to be less convenient in 0-G. Depressing the top plunger displaced the stopper separating the powder and diluent compartments, but the diluent tended to remain within its compartment until it was coaxed into the lower compartment by swinging the vial in an inverted orientation or by shaking along the symmetry axis. Mixing could then be performed in the lower compartment, but the action of bringing the diluent and powder into contact often involved enough agitation to create some foam. The resulting foam, together with the difficulty of transporting the solution back into the upper compartment, made extraction of the drug solution by needle and syringe somewhat problematic. In most cases, it was not possible to withdraw some drug solution and inject it into the target saline bag before the end of a parabola.

Pressurization of the vials due to diluent injection was undesirable since it often caused some drug and diluent to be ejected. Spillage was minimized by pointing the top of the vial toward the chuck taped to the floor of the aircraft as the needle was withdrawn. Zero-G, however, greatly increased the area of distribution of the spray with some drug solution becoming deposited on the investigators hands and on the experiment equipment. Pressurization did, however, appear to facilitate extraction of the drug solution. Absence of pressurization in the Act-O-Vials reduced spillage, but probably contributed to the difficulties with extraction.

Restraints proved to be indispensable for parabolic flight. If the investigator had been free-floating, the risk of accidental needle stick to other personnel on board would have been significantly increased. Also, given the short amount of time per parabola, and the number of items that had to be manipulated, the investigator could not afford to become separated from the experimental equipment by more than about 2 feet. The technique of restraining the investigators lower legs to the floor of the aircraft using tie downs proved to be convenient for 0-G, allowing enough room for arm and centrifuge swings while maintaining sufficient proximity to the work area, but was rather taxing on knee and ankle joints during 2-G pull-ups (although the discomfort was significantly reduced after a seat cushion was placed between the investigators legs and the floor).

DISCUSSION:

The results of this experiment demonstrate that it is feasible to reconstitute powdered drugs in a 0-G environment using standard pharmacological supplies. Some drugs (Rocephin and Diamox) are reconstituted more readily than others (Timentin and Solu-Medrol), however, and some drugs may not be reconstitutable at all (Erythromycin). The most important factor in the success of the reconstitution process was clearly the solubility of the drug. The next most important factors were the mixing method and the gas:liquid

ratio. The shape of the vial appeared to be significant only in the case of the Act-O-Vial system where the double-chamber design tended to interfere with mixing and withdrawal in 0-G, in contrast with it's ease of use in 1-G.

Based on the results of this experiment, several recommendations may be made for reconstitution of powdered drugs during spaceflight:

- Preference should be given to drugs with high solubility. Drugs with moderate solubility may be reconstitutable, but would require greater time and effort to ensure adequate mixing and dissolution. It is likely that drugs with low solubility will be prohibitively difficult to reconstitute in 0-G, unless a surfactant is added to the powder mix or specialized centrifuge equipment is flown.

- The most appropriate diluent must be made available for reconstitution. For instance, the recommended diluent for Erythromycin, namely sterile water, was not available for the experiment, so saline was used instead. If sterile water had been used the efforts to achieve adequate mixing and dissolution might have been more successful.

- Vial size and diluent volume should be chosen so as to approach a gas:liquid ratio of approximately 0.5 to 1.5 to optimize the efficiency of mixing and the ease of extraction.

  The recommended method of mixing (without the use of mechanical devices) is by means of full-length arm swings with the elbow joint extended. If space constraints prohibit full-length arm swings, then forearm swirls with a bent elbow joint may be substituted.

- The use of dual-chamber vials containing both powder and diluent, such as the Act-O-Vial system, is not recommended for 0-G, due to the difficulty in extracting the drug solution. A possible solution to this problem, however, would be to use syringe needles that are long enough to reach the bottom of the vial since the fluid tends to favor the lower compartment. The process of extraction may also be assisted by injecting some air to pressurize the vial.

- Care should be taken to avoid spillage of the drug and diluent due to vial pressurization. The ejected contents of the vial may float around in zero-G and come into contact with a crewmember's eyes or be ingested, thus resulting in undesirable exposure to the drug and possibly an adverse reaction. If pressurization can not be avoided, the vial and syringe should be wrapped in some sort of absorbent towel to catch any of the vial contents that are ejected as the needle is withdrawn.

In conclusion, it is believed that there are no insurmountable difficulties to reconstituting powdered drugs in weightlessness. Some drugs with lower solubility may require greater investment of time and effort, but if they can be reconstituted in 1-G, it should be possible to reconstitute them in 0-G. The chances of successful reconstitution will be maximized by

ensuring that the appropriate diluent is available, selecting vial sizes and diluent volume to optimize the gas:liquid ratio, and making use of a centrifuging device if available.

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PHOTOS:

98EO9312 to 98EO9316
98EO9323
98EO9326 to 98EO9334

VIDEOS:

Medicine Reconstitution 11/12 & 11/13, Tapes 1 and 2, PMU:1147588, Reference Master: provided

20000025630

TITLE:
Undergraduate Program Flights - Physiologic Testing of a Constant Force Resistive Exercise Unit in Microgravity

FLIGHT DATES:
March 17-18, 1999

515/54

PRINCIPAL INVESTIGATORS:

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Paul Colosky, Jr., Colorado State University
Johnathan Dory, Colorado State University
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434286

CO-INVESTIGATORS:

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NASA Photo: 99EO2423

GOAL:

To evaluate the Constant Force Resistive Exercise Unit (CFREU) aboard the KC-135 during microgravity.

INTRODUCTION:

Many aspects of human physiological design are based on the presence of the 1-G gravity vector of Earth. In space, muscles atrophy due to the lack of a gravity vector against which to do work (McArdle et al., 1996). Future possible lunar habitation and the building of the International Space Station (ISS), the primary purpose of which is to accommodate missions lasting from several weeks to several months, has made countermeasures for muscle atrophy an area of major research design and development within the space program.

Both cardiovascular training and strength training are essential during long-term microgravity missions. Numerous countermeasures for the negative physiological effects of microgravity have been designed in the past, including exercise bikes, treadmills, and rubber band devices. However, while these exercise devices provide essential aerobic activity, they lack the ability to provide resistive forces necessary on muscles to replace the gravity vector of Earth. Latest countermeasures also incorporate fluid or air hydraulics for resistive exercise; however, this means of resistance often result in stammered movement patterns during exercise. Furthermore, most hydraulic machines lack the essential eccentric contractions during exercise. Although rubber band devices do provide anaerobic resistive forces, they do not provide measurable **constant quantitative forces** on the muscles that are necessary for optimal muscle maintenance (Harman, 1994). The proposed Constant Force Resistance Exercise Unit (CFREU) is designed to exercise muscle groups concentrically and eccentrically smoothly at a **constant quantitative rate**, therefore simulating the resistive effects of gravity present on Earth (Booth and Criswell, 1997).

The main CFREU design was initially developed by a team of Colorado State University undergraduates as a project for the student branch of the American Institute of Aeronautics and Astronautics in the Spring of 1998. The design is intended to be compatible with ISS modules as a countermeasure for muscle atrophy and bone demineralization. The main CFREU design was modified (CFREU-A) for this KC-135 experiment to meet the requirements of the KC-135 Flight Opportunities for Undergraduates program without sacrificing the uniqueness of the CFREU concept. The unit essentially resembles a Nautilus machine; however, because free weights are useless in microgravity, the constant resistive forces of the CFREU are provided by constant torque springs that are arranged in uniquely designed "force packs."

The CFREU exercise unit meets all of the following requirements for exercise countermeasures against muscle atrophy in microgravity as prescribed by NASA Johnson

Space Center Exercise Physiology Laboratories (Dr. Suzanne Schneider, personal communication).

- Ability to allow both eccentric and concentric muscle contraction during exercise
- Ability to provide a constant force over the entire range of motion of an exercise
- Ability to allow multiple exercises to be performed, thus maximizing a complete body muscle strengthening routine
- Safe to use
- Easy to operate during exercise
- Uses no or minimal power to operate
- Design can be altered to meet various size requirements by the International Space Station
- Can be used in lunar or martian gravity as well as microgravity

To verify the CFREU concept, the physiological testing of our exercise unit was performed in microgravity on NASA's KC-135 airplane as part of NASA's Reduced Gravity Flight Opportunities for Undergraduates Program.

METHODS AND MATERIALS:

Instruments

The CFREU-A that we used in this experiment is the KC-135 version of our main CFREU concept, designed to fit size and safety standards as outlined for the KC-135 flight experiment participation. It consists of a commercially manufactured resistive exercise machine supplied by Task Industries, Inc. that was modified for our purposes to include the ability to perform bicep curls, tricep extension, leg curls, and leg extension. A series of cables and pulleys attached to four force packs located within a Plexiglas trunk was essentially similar to a Nautilus equipment design.

The multiple force packs simulate the weight stacks on a typical Nautilus machine. The resistive force provided by each force pack consists of one or more constant torque springs, which offers a variety of constant resistive forces during exercise.

The force packs were located within the force pack trunk, which consisted of the following: one 30 lbs. force pack, one 15 lbs. force pack, and two 10 lbs. force packs. Each spring material thickness was 0.081", and the material width was 1.00", type 301 stainless steel. The size of each spring had an uncoiled length of 58" and an inner diameter of 1.82" when coiled. The average weight of one force pack averaged approximately 10 lbs., and the average dimensions of a force pack was 12" x 5.25" x 12".

Procedure

To validate the proposed CFREU force pack resistance concept, our KC-135 research protocol required one individual (n=1) to perform simple exercises on the CFREU-A during the microgravity portions of flight. Surface electromyography (sEMG),

goniometry, and force gauge measurements were used to collect various physiological data from the individual during exercise in microgravity and on the ground.

In-flight Testing Procedures

The muscles chosen for this experiment were those that are known to be affected by long-term microgravity conditions as described previously (Lujan and White, 1994). These muscles include the biceps brachii and triceps (upper arm), biceps femoris (hamstring group), and rectus femoris (quadricep group).

Approximately one hour before flight, non-invasive sEMG disposable surface electrodes were placed on the skin of the exercise subject over each muscle selected to be tested. Table 1 depicts the KC-135 research protocol and selected muscle groups and exercises that were performed in-flight, and then later during ground-based data collection.

Table 1: Research protocol (in-flight CFREU-A, ground-based CFREU-A and ground-based Nautilus-type Equipment)

Muscle	Exercise	Amount of Resistive weight
Rectus Femoris (quadriceps)	Leg Extension	30 in-lbs.
Biceps Femoris (hamstrings)	Leg Curl	30 in-lbs.
Biceps (upper arm)	Biceps Curl	15 in-lbs.
Triceps (upper arm)	Triceps Extension	10 in-lbs.

Throughout the microgravity portions of the flight, the exercise subject performed one exercise per selected muscle using the CFREU-A, while the other team member collected sEMG data. The sEMG data was obtained by a Smith and Nephew Musclesense II clinical amplifier and surface electrodes with measurement capabilities of muscle electrical activity of 0.01 - 1000 microvolts. Raw sEMG output was translated by a National Instruments DAQ 1200 data acquisition card and National Instruments LabView software from a laptop computer. After sEMG data was collected, hand-held force gauge readings were obtained on a 15 lb. force pack at an arm angel of 90° during a bicep curl exercise to ensure that the resistance level of the springs of the force packs was optimal in the microgravity environment. The force gauge we used was a hand-held force gauge series HFG-45 by Transducer Techniques, Inc.

Ground-based data collection

Pre-flight readings were obtained directly from a goniometer and the force gauge during only bicep curl exercise at elbow flexion angles of 180°, 135°, 90°, and 45°. (This

goniometer concepts and its relationship to the joint angles that are measured was previously discussed in the literature (Smith et al., 1996).) The goniometer measurements ensured a full range of motion during exercise with the CFREU-A. Hand-held force gauge measurements were taken on a spring within the 15 lb. force pack to verify the force output of the spring.

For the comparative analysis of physiological data between ground-based exercise and microgravity-based exercise with the CFREU-A and Nautilus-type machines, ground-based protocol similar to the microgravity-based protocol was performed after the KC-135 flight. SEMG data was taken during exercise on the same individual who performed the in-flight exercise. The selected exercises were performed on Cybex and Serious Training Series brand equipment (Nautilus-type equipment), and the forces produced by the weight stacks were measured using the hand-held force gauge. The amount of resistive force was the same as in-flight for each exercise.

RESULTS:

Acute physiological evaluation of the CFREU-A and the force pack concept was performed on the ground and in microgravity using sEMG to measure muscle activation patterns during leg extension, leg curl, bicep curl, and tricep extension exercises. These muscle activation patterns were then compared to sEMG patterns produced during similar exercises using ground-based Cybex and Serious Training Series brand Nautilus-type exercise equipment.

Preliminary results obtained from average sEMG peak amplitudes of muscle activity during all exercises with the ground-based CFREU-A were similar to the average sEMG peak amplitudes of muscle activity during exercise with the Cybex and the Serious Training Series brand units. These results indicate that muscle response during exercise with the CFREU-A is identical to Nautilus-type units. Further analysis of the sEMG data when using the CFREU-A in microgravity proved also similar to the ground-based CFREU-A and the Cybex units.

Raw sEMG readings reflect eccentric and concentric muscle contractions during all exercises that are similar for the CFREU-A and the Cybex in ground-based and microgravity. However, raw sEMG hamstring and quadriceps data in microgravity revealed less precise contractions, which was likely due to the exercise subject attempting to orient himself properly in the seat in microgravity, despite restraining belts. Ground-based raw sEMG data reveals a more exact muscle contraction pattern for quadriceps and hamstrings for both the Cybex and the CFREU-A.

Exercise with the CFREU-A was smooth and frictionless, similar to a Nautilus-type machine. There were no difficulties with spring failure within force packs, and each provided an optimum amount of resistance for exercise. The unique CFREU-A design proved to be reliable, stabile, and safe throughout each exercise both in microgravity and on the ground.

DISCUSSION/CONCLUSION:

As the future of the space program promises long-term exploration missions, lunar habitation, and the building of the space station, production of reliable countermeasures for muscle atrophy and bone calcium loss in microgravity has become increasingly essential. Since typical weight stacks are useless in microgravity, a similar means by which to provide constant force during eccentric and concentric contraction is necessary during exercise. The KC-135 flight provided a valuable means by which to validate the CFREU-A and the unique force pack design in microgravity. SEMG data reflected real-time muscle response during in-flight and ground-based exercise, and force gauge readings validated the constant force capabilities of the constant torque springs within each uniquely designed force pack.

As we expected, sEMG data and force gauge data indicate that the force packs within the CFREU-A performed as well as the weight stacks on the Cybex unit, both in microgravity and on the ground. The constant torque springs within each force pack maintained their resistance level and a constant force over the entire range of each exercise. SEMG data concerning concentric and eccentric contractions further validated the force packs within the CFREU-A as a means by which to obtain an effective strengthening routine both in microgravity and on the ground.

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PHOTOGRAPHS:

99EO2397 to 99EO2398
99EO2423
99EO2441
99EO2520 to 99EO2522
99EO2526
99EO2543

VIDEO: provided

TITLE:
Undergraduate Program Flights -The Effects of Microgravity on Multidrug Resistance

FLIGHT DATES:
March 20, 1999

PRINCIPAL INVESTIGATORS:

Jennifer Buchli, The University of Texas at Austin
Tony Afghanipour, The University of Texas at Austin
John Boone, The University of Texas at Austin
Darren Boyer, The University of Texas at Austin
Dustin Dinh, The University of Texas at Austin
Emily Hueske, The University of Texas at Austin
Jeremy John, The University of Texas at Austin
Angela Martin, The University of Texas at Austin
Jay Sanampudi, The University of Texas at Austin
Ed. Piepmeier, Ph.D., The University of Texas at Austin

NASA Photo: 99EO2717

GOAL:

To study drug diffusion across cell membranes and structural alterations under microgravity conditions.

OBJECTIVES:

1. To identify changes in drug transport across the membranes using HL-60 and Jurkat cell lines.
2. To reproduce our previous findings and determine if these findings are specific to the HL-60 cell line.
3. To determine if active transport is affected under microgravity conditions by altered microtubule formation and changes in protein regulation.

INTRODUCTION:

Response to drugs is predicated on transport mechanisms, expression, and activation of cellular receptors and enzymes. This mechanism of transverse migration of drugs across membranes is of fundamental importance to understanding drug delivery, because all drugs must cross membranes of one kind or another. The purpose of this experiment was to identify the effect that microgravity may have on multidrug resistance in leukocytes. Multidrug resistance (MDR) is the ability of a cell to withstand a broad spectrum of chemically related drugs following selection by only one drug. Studies conducted on MDR activity, because of its intrinsic complexity, provide insight into cellular function and drug action. The condition of microgravity was incorporated in developing a model to enhance our understanding of basic molecular mechanisms associated with drug action. The cytoskeleton is highly sensitive to changes in the microgravity environment. Cytoskeletal interactions with surface proteins are critical to the function of proteins as drug efflux pumps. The activities of surface proteins that are involved in MDR, such as the P-glycoprotein, are linked to membrane fluidity and the cytoskeleton. The experiment conducted was designed to analyze the cellular response associated with Doxorubicin activity in leukocytes under short-term weightlessness.

Experiments were conducted during NASA's KC-135 flights and Space Shuttle missions STS-67, 69, 77, 80, and 95. Doxorubicin was used as a model drug that has been well characterized in cellular studies of MDR. Doxorubicin distribution is a marker for drug transport and the functionality of MDR. Promyelocytes were selected as a model cell because the immune system exhibits significant alterations in Space. We used promyelocytic cell lines HL-60 and Jurkat, examined previously with respect to delivery of Doxorubicin on Earth. Influences of gravity on cellular function assist us in understanding events on Earth, as well as in projecting the long-term influences that may impede future Space exploration.

METHODS AND MATERIALS:

Preparation of the HL-60 and Jurkat cells
The HL-60 and Jurkat cell lines were kindly provided by Dawn Chapman (Johnson Space Center Life Sciences) and Dr. Marian Lewis (The University of Alabama Huntsville). The cell lines were grown in RPMI with non-essential amino acids, sodium pyruvate, 100 IU penicillin, 0.1 mg streptomycin, 0.3 mg glutamine, and 10% fetal bovine serum. All chemicals and cell culture supplies were obtained from Sigma, St. Louis. Ground controls were treated with the same protocol and in identical equipment as the flight samples. The experiment was conducted with cells in RPMI media at a concentration of 1,500,000 cells per ml. Upon reaching weightlessness, cells were exposed to media containing Doxorubicin®, and after roughly 20 seconds (prior to the end of temporary microgravity) the cells were mixed with a fixative. The following table outlines the volumes and concentrations of the experiment samples:

Cell	Doxorubicin	Fixative
HL-60 3mL	3mL at 2µg/ ml	0.3% glutaraldehyde/ 6% paraformaldehyde
HL-60 3mL	3mL at 20µg/ ml	0.3% glutaraldehyde/ 6% paraformaldehyde
Jurkat 3mL	3mL at 2µg/ ml	0.3% glutaraldehyde/ 6% paraformaldehyde
Jurkat 3mL	3mL at 20µg/ ml	0.3% glutaraldehyde/ 6% paraformaldehyde
Jurkat 2mL	2mL at 2µg/ ml	6 ml RNAlater™
Jurkat 2mL	2mL at 20µg/ ml	6 ml RNAlater™

Table 1

Instruments
Hardware for the KC-135 flight experiments consisted of minirobots, kindly provided by Dr. Marian Lewis and developed by the Consortium for Materials Development in Space. Attached to each robot were three syringes connected together by a valve that directly connected only two syringes at a time. The syringes contained: A) test cells, B) Doxorubicin®, and C) fixative. There were eleven robots for use per flight, providing a total of 22 samples for two flights.

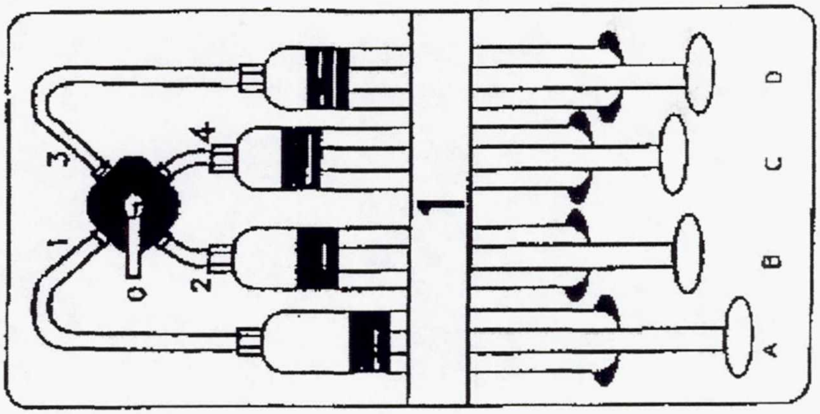

Figure 1

Procedure

Each of the seven robots was contained inside its own Zip-lock® bag, and they were individually anchored to the cabin by seven-foot sections of ribbon. The tether allowed the robots to float without obstruction during weightlessness. Upon reaching microgravity, created by a KC-135 parabola, the drug of the indicated volume in Table 1 was added to 1,500,000 cells per ml. Before the KC-135 concluded its free fall, a fixative agent was added to the cell/drug solution. The cells were exposed to the drug for approximately 20 seconds (15-25 seconds) for each parabola.

RESULTS:

The principle investigators are conducting analysis at The University of Texas, Austin and The University of Texas Health Science Center, San Antonio. Doxorubicin distribution is being studied with fluorescent microscopy.

Image analysis is being conducted in individual calls from each treatment. Genetic regulation is being studied at the mRNA level using the Atlas™ cDNA Expression Array. Results will be presented at The San Antonio cancer Institute's 9th Annual Symposium on Cancer Research July,1999.

DISCUSSION/CONCLUSIONS:

It is too early in our data analysis to draw specific conclusions at this time. Further discussion regarding the progress of the experiment will be accessible at the following web site:

http://www.utexas.edu/pharmacy/divisions/pharmaceutics/kc135/index.html

PHOTOGRAPHS:

99EO2701
99EO2704 to 99EO2705
99EO2707 to 99EO2709
99EO2712 to 99EO2713
99EO2717
99EO2728
99EO2778 to 99EO2781
99EO2803
99EO2810 to 99EO2811

VIDEO: provided

2000025632

TITLE:

Undergraduate Program Flights - High Altitude *Drosophila* Science Experiment

FLIGHT DATES:
March 20, 1999

5,7/51
434558

PRINCIPAL INVESTIGATORS:
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Megan Carroll, University of Vermont
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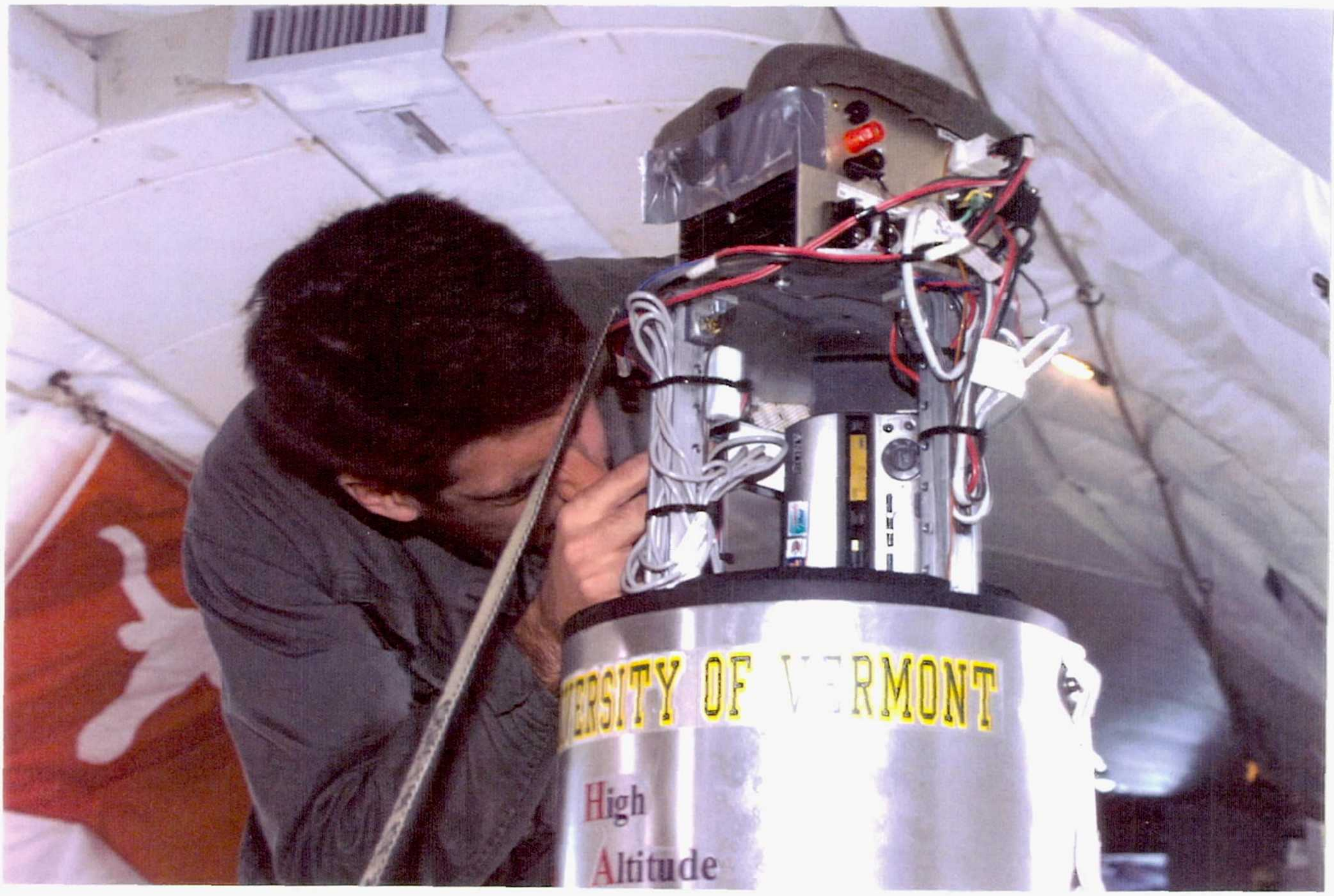

NASA Photo: 99EO2701

GOAL:

The University of Vermont proposes to determine whether the equipment and design of our experiment is capable of functioning properly under micro gravity conditions. In addition, the KC-135 test bed allows the examination of short-term micro gravity effects on fruit flies as well as varying gravitational loads on *Drosophila*.

OBJECTIVE:

Undergraduates of the University of Vermont (UVM) are participating in NASA's Student Launch Program conducting biomedical science aboard a Nike-Orion sounding rocket. UVM was selected along with two other sounding projects from across the country. The UVM project--"Effects of a Sounding Rocket Flight on *Drosophila*"-- is a biological experiment to confirm earlier findings that young male *Drosophila* fruit flies exposed to micro-gravity have an acceleration in their aging. The theory is that aging is the consequence of increased locomotion and the objective of the experiment is to measure the activities of the flies during the flight. Previous experiments have theorized that male *Drosophila* exposed to micro-gravity space flight have shortened life spans due to their increased motility and, in turn, their metabolic rates. Important advances in the understanding of the aging process, including humans, could be obtained through comprehending the changes experienced by the flies under these reduced gravity conditions.

Increased motility is believed to be due to *Drosophila's* negative geotaxis response. A negative geotaxis response is an inherent trait of the *Drosophila* to move in the opposite direction of the Earth's gravitational vector when stimulated. This negative geotaxis response is primarily manifested as a walking response. This trait is present in nearly all *Drosophila*, although various levels of negative geotaxis are prevalent. Three *Drosophila* types with respect to negative geotaxis activity are to be evaluated: Normal vs. Hyperactive vs. Non. Within these different types, different characteristics will be taken into consideration: Males vs. Females as well as Young vs. Old.

During the brief exposure to micro-gravity, the time course of the increased activity was examined as to whether the negative geotaxis response is the cause of the increased activity. Other parameters such as temperature and acceleration were measured to determine the exact conditions that the *Drosophila* experienced.

INTRODUCTION:

Drosophila has been used in experiments for years because of the very high similarity of their DNA to humans. Increased activity during space flight has been theorized to cause the reduced life span observed in male *Drosophila* exposed to long-duration micro gravity. Important advances in the understanding of the aging process, including humans, could be obtained through comprehension of the changes experienced by *Drosophila* during reduced gravity conditions. Analyzing the KC-135A flight data will allow us to study the accelerated aging process and will also allow us to test new hardware, which automatically measures the activity and metabolic response of a group of *Drosophila*.

METHOD AND MATERIALS:

During the KC-135A reduced-gravity flight, the effect of the exposure of *Drosophila* to micro gravity was monitored. The experiments were conducted in a self-contained unit

that was fastened to the floor of the aircraft. Two students were present to perform the experiment. A video camera was operated by one student, primarily concerned with monitoring the test bed during the short duration of micro gravity. A second student observed the infrared monitoring system to ensure it was functioning properly. This student also was required to visually monitor (record if necessary) the activity of the flies to determine the validity of our experimental data.

Success of the experiment is based on the following:

- Ability of the temperature control system to maintain the temperature of the payload between the minimum of 20 and maximum of 25 degrees Celsius.
- Proper operation of the infrared monitoring system and the subsequent collection of data is required.
- Acceleration data from the accelerometer is necessary so that micro gravity conditions can be identified to correlate data collected from all of the experiments performed.

Flies are the primary concern of this mission and they have a specially designed chamber used to monitor the activity of each fly in the test groups. Our test bed will consist of one tower of 12 chambers, containing a total of 120 flies. Each holding chamber contains 1 fly, 2 infrared emitters and receivers each located equal distance from the center. When a fly breaks the infrared beam, the event is recorded in the attached data loggers. The chambers are symmetrical and have both a food supply and air hole at each end. The alignment of the chambers was both in the vertical and horizontal positions to eliminate any significance of that variable in the data collected. The fly activity on a separate fly plate was also recorded with a camcorder and light source.

Design of payload structure and the selection of equipment for the flight are based upon requirements needed for the experiment. The experimental apparatus consists of a 12" diameter structure that stands 48"high and it was bolted rigidly to the floor. The structure built and all equipment used on the KC-135A flight was based on the design that is going onboard a Nike-Orion sounding rocket launch. The cylinder contained: (1) Experimental fly chamber with subsystems for monitoring and recording movement (2) Internal support structure consisting of vertical columns and horizontal platforms (3) hardware: accelerometers, camcorders, and other supportive equipment. (4) Power Supply to support all subsystems.

Limited hardware was needed for the flight. An accelerometer (Setra model #141A) was used to collect gravitational data on the flight as a function of time. One camcorder and light source will be mounted to the internal structure for the purpose of filming the movement of the flies, and an additional light source will be available if needed. A PC connection wired from the experimental apparatus was used with a laptop to download, store and analyze the data collected. The PC was mounted to the experimental structure.

The use of a microprocessor based evaluation board configuration enabled us to obtain quantitative data regarding *Drosophila* activity levels. The evaluation board is used to

process the infrared (IR) analog voltage changes and to record the information in a comprehensible manner. The resulting data was transferred to a personal computer during the course of the flight for later analysis.

RESULTS/DISCUSSION:

The KC-135A micro gravity flight was successful in gathering activity rates of the *Drosophila* both as hard data and with video. The experimental support equipment proved to work when the proper setup was achieved. On the first flight the bottom insulation was left off to prevent overheating, but our system remained to cold. On the second flight the insulation was attached again and the system held a fairly constant 25 degrees Celsius. Both the temperature trend lines generally increased with time of flight. The temperature control/power supply box worked without a problem on both flights. It delivered proper environmental control commands along with a range of power levels to each electronic component. The preliminary video analysis shows that the *Drosophila* have an increased motility rate during micro gravity. The hard data from the IR collection plates has not been fully analyzed to determine the activity rate of the *Drosophila* during micro gravity. Preliminary findings suggest increased motility occurs for the flies, but no life span data is available.

CONCLUSION:

At this time, no scientific conclusions about motility and life span correlations can be made until our data is fully analyzed. The temperature control and power supply box have performed well under micro gravity conditions.

PHOTOGRAPHS:

99EO2701
99EO2704 to 99EO2706
99EO2716
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99EO2774
99EO2776 to 99EO2777
99EO2805

VIDEO: provided

TITLE:
Undergraduate Program Flights -The Mixing of Intravenous Fluids in a Micro-gravity Environment

FLIGHT DATES:
March 24 -25, 1999

INVESTIGATORS:
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Stephanie Thouvenel-Romans, Embry-Riddle Aeronautical University
Ed Springer, Embry-Riddle Aeronautical University
Shiju Nair, Embry-Riddle Aeronautical University

NASA Photo: 99EO3078

GOALS:

To test whether two intravenous fluids would efficiently mix in a reduced gravity environment with the use of different velocities applied with pumps. This study will help to develop new ideas on how to decrease overall effects with new procedures of intravenous solutions into the bloodstream. By observing the two different fluids interact, theories

such as the formation of air bubbles or eddy currents in the blood flow will become either confirmed or disproved. An air bubble or some extreme turbulence in the blood flow would mean life-threatening consequences to the astronaut in need.

OBJECTIVE:

The objective of this experiment is to determine how two different fluids interact in an artificial vascular system in a free fall environment. Two series of experiments will be conducted. A first series of data sets will be collected in normal gravity conditions (1g) and a second set of data will be collected in micro-gravity. The purpose of this experiment is to see how two different fluid flows behave and interact in reduced-gravity.

The data will be taken in form of visual observation using a video camera and high-speed digital camera attached to the box. The observations will include the rate and the way of mixing fluids, speed and intensity will be recorded on video camera, while the digital camera will show detailed phases of the mixing.

The expected result of the experiment is to observe the rapid, homogeneous mixing of the fluids, however, in micro-gravity the behavior of fluids can change. Among the possible results are the formation of bubbles of fluid, air bubbles or the formation of eddy currents. The reason for those assumptions is NASA's observed behavior of fluid in reduced gravity. The blood will tend to distribute differently in micro-gravity, with more pressure in the head and chest.

INTRODUCTION:

The experiment consisted of a pump regulating a yellow fluid simulating blood from a reservoir through a tube to another receptacle. The secondary pump regulated the injection of a blue fluid (saline) in the stream. A primary pump will be activated a few seconds before reaching micro-gravity to allow enough time for the yellow fluid to attain the desired flow rate and laminarity. As soon as the effects of micro-gravity start, the secondary pump will inject the blue fluid inside the test section for the duration of the free fall. By regulating both pumps' velocities we will observe the way these two fluids will dilute or separate.

A fixed camera inside the housing will record the visual data. A graded white board will be installed inside the Plexiglas casing protecting the experiment to facilitate the measurement of fluid flow as well as sizing any bubbles that might occur. Observations will primarily focus on the interaction between the two fluids. This experiment is based on fluid dynamics and is very complex in its nature, as we will not only deal with laminar flow but it is expected that the flow will be turbulent. The Reynolds number is a non-dimensional constant, which describes the nature of the flow inside a circular pipe. It represents the ratio of the inertial forces to the viscous forces.

METHODS AND MATERIALS:

List of Equipment

- Plexiglas tube (test section) and plastic tubing
- Pumps/motor
- Video camera
- Water based liquids
- Protective casing
- Shower bags
- Non-rechargeable batteries - NiCad
- External reservoirs

Test section and plastic tubing:

The test section will be a piece of Plexiglas tubing. This material was chosen for its high weights and yield strength. The most important factor was the coefficient of transparency of the material since visual data will be collected. Once the two fluids have passed through this area, they will flow to the receptacle through the plastic tubing.

Pumps/motor:

The primary pump will be used to give the yellow fluid (blood) the desired speed through the test section and plastic tubing. A 15 V battery located in the base will power the pump's motor. A second pump, smaller than the primary, will be used to pump a blue liquid that will act as the IV saline fluid. Regular 1.5 V batteries will power the secondary pump. No power will be drawn from the plane electric supply.

Photographic equipment:

The photographic equipment will include a video camera recording the totality of the flight's effect on the fluids in the test area.

A graph paper will be placed behind the Plexiglas tube to allow a better reading of the colors.

Protective covering:

The protective covering will prevent the experiment from being damaged from external hazards as well as shield the people on board from flying loose parts in the event of an accident. The choice was made to use .25 in. Plexiglas for the top casing sealed to a steel frame for rigidity. The base will be made out of an Aluminum alloy to protect the battery and the reservoirs.

Procedure

Table 1 : In-Flight team member assignments and procedures.

Time	Team Member 1	Team Member2
-Prior to the parabola set	Examine the experiment	Set the electrical pump
-Prior to μ-gravity	Observe the electric pump start-up	Start electrical pumps
-During μ-gravity	Observe the fluid flow	Vary rate of flow (second half)
-After μ-gravity		Stop electrical pumps
-After parabola set	Examine the experiment	Check pumps and gather results

General Checklist:

1. Verify that the equipment is firmly fixed on the KC-135 A floor.
2. Start electrical pumps
3. Observe the fluid flow
4. Vary velocity of fluid
5. Stop electrical pump

For this experiment the 40 parabolas will be sufficient to carry out the test. Each parabola will qualify as an individual experiment, this means we will number each parabola for future references and to keep track of our data during the parabola.

RESULTS/CONCLUSIONS:

The Intravenous experiment was designed for long duration space stays already taking place and with the upcoming Space Station. Our concern was that an intravenous fluid system could become essential in certain situations. IV systems on Earth usually depend on gravity to force the fluids into veins. This is why a saline bag has to be positioned in an upright and downward fluid flow motion. This method obviously would be ineffective in micro-gravity.

During 1g testing, we discovered that both fluids needed an external force (pumps) to dilute and mix well. Even though the mixing of both fluids took place and the color blue was achieved, the yellow liquid with the highest density tended to rest in the bottom of the

tube while the blue liquid with the lowest density tended to rest above the yellow fluid. It is true, when you test an experiment on the ground gravity tends to pull down the densest liquid making it a little difficult to obtain the desired results requiring a high external force to mix them.

What we discovered in micro-gravity was that for all velocities the fluids of different viscosity and density mixed well. The resulting green fluid was produced under every circumstance we tested in micro-gravity. While both liquids rested inside the tube, they automatically mixed when reaching a zero-gravity environment. No external force had to be applied for both of these fluids to interact with each other under a closed environment. These results were very pleasing as we realized that mixing intravenous fluids in micro-gravity is very ideal. This same conclusion has been proved with crystalline formation. The homogeneity of the resulting fluid was beyond what we anticipated. The behavior of the two fluids also created a turbulent flow in the T-section where both fluids interacted. This is safe if the turbulent flow is not extreme. Natural laws specify the behavior of two liquids acting upon an external force where they mix due to the turbulent reaction between one liquid been poured into another. Even though we used the pumps to help achieve the desired results of mixing, neither of them was needed when two fluids are together in a closed environment. Pumps are helpful (like the heart) and when the mixture of liquids need to travel a distance with the help of an external power.

We hope that our experiment can aid in the future advancement of life sciences in space.

PHOTOGRAPHS:

99EO3002 to 99EO3003
99EO3073
99EO3078

VIDEO: provided

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TITLE:
Undergraduate Program Flights - PREVIEW - PeRiphEral VIsion Experimentation in Weightlessness

5,9/53
434560

FLIGHT DATES:
March 26-27, 1999

PRINCIPAL INVESTIGATOR:
Cory R. A. Hallam, Massachusetts Institute of Technology

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Julie Gesch, Massachusetts Institute of Technology
Dava Newman, Massachusetts Institute of Technology
Tyra Rivkin, Massachusetts Institute of Technology
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NASA Photo: 99EO3199

GOAL:

This research was aimed at determining the effects of zero gravity on peripheral vision field of view limits in humans, and the subsequent implications related to the design of spacecraft and space station working environments.

OBJECTIVE:

To develop and fly a head-mounted apparatus capable of detecting the peripheral vision field of view limits in test subjects flying in simulated zero gravity in the NASA KC-135 reduced gravity aircraft.

INTRODUCTION:

It is well-known that humans subjected to hyper-gravity environments experience the phenomenon of peripheral light loss (PLL) or tunnel vision as it is more commonly known, which is characterized by a narrowing of the visual field. Research on this subject has developed largely in connection with the advent of the high-performance combat aircraft where pilots are routinely subjected to loads of up to 9G for brief periods of time. This information has led to new design considerations for cockpit layouts, in particular the position of mission critical equipment; however, little research has been done to explore the effects of micro-gravity on the peripheral vision field of view (FOV) limits in humans. With the increase in human space-based activity planned for the International Space Station (ISS), the question of knowing if there is a corollary FOV design concern for spacecraft and space station working environments becomes important. This experiment was established to explore the peripheral vision FOV limits in humans in the micro-gravity environment.

The eye experiences 20 mmHG of blood pressure in a standard Earth-based (1G) environment. As G-levels increase, the arterial pressure in the eye drops. Once the arterial pressure drops, the oxygen flow to the retina diminishes and visual sensation is lost. The peripheral regions of the retina get blood after arterial branch points, thus a pressure drop occurs between the central and peripheral portions of the retina. As such, the peripheral limits of the retina will lose the oxygen supply at lower G loads than the central portion of the retina. Hence the human exposed to hyper gravity will initially lose peripheral vision, a condition known as peripheral light loss (PLL), with the onset of hyper G. With a continued increase in G-loading, the arterial pressure to the center of the retina will also drop, resulting in a complete loss of sight or blackout as it is commonly known. Upon return to 1G conditions, the human will regain sight as the blood-flow to the retina is re-established.

Based on the above discussion of human ocular physiology, one becomes interested in asking if the micro-gravity environment could lead to a change in the peripheral vision FOV limit in humans, especially with an increase in hydrostatic arterial pressure in the retina during 0G flight. The PREVIEW experiment was designed to develop data that

would determine whether there is a perceptable change in the peripheral vision FOV limits in 0G flight, as a basis for

a) establishing a need to develop a physiological model of the effects
b) setting design guidelines for space-flight vehicles

METHODS AND MATERIALS:

This experiment used a self-contained helmet system that provided a moving ocular stimulus to the test subject's peripheral FOV. By controlling the movement of the stimulus, the test subject positioned the stimulus at the peripheral FOV limit, and an electronic data logger recorded the position of the stimulus. All tests were performed on the left-hand eye within a light-sealed environment. Based on physiological measurements of the test subjects, the relative position of the stimulus with respect to the eye was determined, and a direction angle was subsequently calculated between the direct forward gaze and the peripheral FOV limit.

The experiment design team built two flight assemblies that were identical, and could be interchanged in flight in the event of a failure. The flight test team consisted of four individuals, each of which would take data during the 0G (push-over) and 2G (pull-out) portions of the flight parabola. For each parabola, an average of two data points were taken during the 0G flight regime, and 3 data points in the 2G fight regime (actually quoted as 1.8G from the flight crew). As such, statistically valid test data were established for 0G, 1G, and 1.8G for three of the test subjects, the fourth was unable to participate due to motion sickness. The intent was to provide data that would show any trends for the transition from hyper-G to 0G flight.

RESULTS:

Each test subject exhibited different results. The first subject demonstrated an increase in the peripheral FOV limit of about 8 degrees for both the 0G and 1.8 G case, as compared to the baseline 1G case. The second subject demonstrated a decrease in the peripheral FOV limit of about 4 degrees for both the 0G and 1.8 G case, as compared to the baseline 1G case. Finally, the third subject demonstrated no significant change in peripheral FOV limit throughout the entire G-regime. Also notable was the fact that the standard deviation of the results were, on average, much higher in the 0G and 1.8G regime than in the 1G regime

DISCUSSION/CONCLUSIONS:

The primary point of interest established by this experiment was that there are individuals who experience significant peripheral vision field of view limit changes when exposed to micro-gravity environments. This result then raises the question of why they experience these changes, a topic for further study. Perhaps as important is the fact that the changes

are highly non-linear, a point that needs to be reinforced when individuals try to extrapolate results to 0G from 1G and hyper-G data.

Also a significant finding was that no over-arching trend between the G-load and the FOV angle was established from the results of this experiment. This suggests that the low number of test subjects, and the many uncontrollable variables, make it difficult to develop quantitative guidelines about the peripheral vision FOV limit in humans without further study.

Finally, both the qualitative and quantitative test data indicated that the test subjects had more difficulty concentrating on the experiment during the 0G and 1.8G flight regimes. This observation is supported by the increase in the standard deviation of the data as compared to the 1G ("normal") results, as well as personal accounts from the test subjects. As all test subjects were first-time flyers on the KC-135, there may be some task-time effects at play where the division of labor between the neuro-vestibular system in the body and the work-load of the experiment changed as the subjects adapted to the varying flight environments. Further research into this fact may reveal existing data about this observation and may be substantiated by repeating the experiment with test subjects fitted with EEG electrodes on their heads to measure changes in brain activity to indicate mental work-load. This would also lead to the question of long-duration micro-gravity (i.e. greater than 20 seconds on the KC-135). It may be more appropriate to verify these effects during a space mission once the body has adapted to the micro gravity environment.

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VIDEO: provided

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TITLE:
Undergraduate Program Flights - Localization of Sound in Micro-Gravity

FLIGHT DATES:
March 26-27, 1999

520/71

PRINCIPAL INVESTIGATORS:

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NASA Photo: 99EO3204

GOAL:

To determine whether or not the ability to localize sound is gravity dependent.

OBJECTIVE:

This experiment attempts to find out exactly what effect a micro-gravity environment has on the human body's ability to localize sound in the horizontal and vertical plane as related to the head.

INTRODUCTION:

Four members of team sound localization (SoLo) from MIT flew aboard the NASA's KC-135a to perform an experiment attempting to find out the effects of reduced gravity on the ability to localize sound. This paper details the experiment performed by SoLo and attempts to analyze the data taken aboard the airplane.

Perhaps the most common sensation that astronauts immediately experience in micro-gravity is severe disorientation. Often this sensory "confusion" leads to space sickness or space adaptation syndrome. Since sound localization is a critical skill that astronauts use to regain their bearings, careful study of sound localization in the micro-gravity environment is required. A better understanding of directional hearing may yield new insights into space sickness and aid in the design of spacecraft, space communication systems, and earth-bound space simulators.

Sound localization is a complex computational task that the brain performs with apparent ease. The brain uses a combination of interaural, monaural and dynamic clues to determine the location of a sound.

When a sound wave hits the head, it is picked up by one ear. Then the head itself distorts the sound wave, and the distorted wave is picked up by the second ear. The distortion introduced by the head is uniquely determined by the incident angle of the incoming wave.

Early in development, the brain learns to compute the differences between the two waves processed by the ears and uses this information to determine sound location. In effect, the brain creates a head-related transfer function (HRTF) which describes the relationship between sound waves received by the two ears as a function of the sound's origin. Since the topology of every head is unique, each person uses a different HRTF. When a person hears a sound, each ear transduces a sound wave into an electrical impulse which is sent to the brain for processing. The brain analyzes the two waves and computes the inverse function of the HRTF to precisely determine the sound's origin.

In addition to the interaural clues derived from the HRTF, each ear has tools to help determine sound location. The crevices, folds and contours of the outer ear, reflect sound waves in different directions as a function of frequency and incident direction. If an identical sound is played from two different spatial locations, it will generate two different spectral histograms because frequencies are differentially amplified by the folds of the outer ear depending on their original location. Another monaural clue that each ear can use is the echo time delay sounds produce as they reflect off of the physical environment.

Given the echo delay time and visual knowledge of the environment, the brain can narrow down the possible locations that a sound could have originated from.

Finally, head motion can drastically improve the accuracy of sound localization. By gathering multiple sets of sound data corresponding to various head positions, the brain can both interpolate and triangulate the location of a sound. Humans use this trick constantly as a means of identifying whether a sound is coming from the front or back, since most interaural and monaural clues do not help in answering this question.

In micro-gravity, a host of physiological changes afflict the body. One of the most fundamental physiological changes is the increase of blood flow to the brain. How exactly brain function is affected by this increase in blood is far from understood. Hearing is doubly affected by micro-gravity: in addition to brain blood flow increases, fluids in the inner ear are disturbed. It is entirely likely that these conditions could cripple the brain's ability to accurately judge sound direction through a mechanism such as interference with the computation of the HRTF.

Another possible theory is purely psychological. It is entirely possible that the ability to localize sound may be tied into a mechanism which relies on the human knowing which way is down. Removing this "down vector" may remove this mechanism, and therefore remove the ability to localize sound.

Early research by Soviet scientists showed that sound localization accuracy could drop by as much as thirty percent after prolonged muscle inactivity and increased blood flow to the head (such conditions are present in micro-gravity). The Soviets collected this data by confining test subjects to bed for prolonged periods of time, and then taking measurements.

Before more detailed research can be described, it is necessary to understand the conventions governing the auditory spatial coordinate system. Three orthogonal planes are used to define the coordinate system. The horizontal plane is the one that is parallel to the ground when standing (it contains the eyes and the ears). The median plane contains our body's vertical plane of symmetry. The frontal plane is mutually orthogonal to the other two planes and intersects them at the center of the head.

In 1991, a joint Austrian-Soviet experiment on the Mir space station called AUDIMIR tested a cosmonaut's ability to accurately localize sounds. The AUDIMIR test suite was designed to determine how precisely a cosmonaut could auditorily determine the forward direction. AUDIMIR results demonstrate that although spatial hearing in micro-gravity is largely unaffected in the horizontal plane, sound localization in the medial plane is shifted ten degrees downwards. In other words, the cosmonaut test subject thought that sounds came from ten degrees lower than where they actually did.

In addition, the AUDIMIR experimenters tried to determine if directional hearing becomes a more important sense in micro-gravity than in one-G. They hypothesized that if sound

localization were more important in micro-gravity, then it would be easier to "trick" a cosmonaut into feeling a sense of motion due to hearing a moving sound source. AUDIMIR showed that a counterclockwise rotating sound source could in fact mislead the human mind into thinking it was spinning clockwise. However, whether the illusion of motion was greater in micro-gravity than under normal gravity conditions is still unclear.

In order to simulate spatial sound for this proposal without going to elaborate means, binaural sound is played for the test subjects. Binaural sound is a technique to create spatial audio (three dimensional instead of the traditional left and right) using only a simple set of stereo headphones.

Stereo sound is usually recorded with two or more microphones. Each microphone is mounted to listen to a separate part that the recorder wants noted. These sounds are then mixed together and edited to be emitted from two separate channels. Because of this, stereo sound requires two loudspeakers and an infinite number of channels to produce a perfect recording.

Binaural sound recordings take the recording situation and make it a little more realistic by closely mimicking how the human body listens. Binaural recordings are usually done with two omnidirectional microphones mounted at the entrance to the ear canals on an artificial head. This artificial head has the microphones mounted 6 to 8 inches apart, and may even have an equivalent of the fleshy ridges of the outer ears to modify the frequency balance of sounds depending on the direction (relative to the head) in which they originate. This head is placed wherever the recorded wishes the listener to be placed while listening.

To simulate binaural sound, transformations can be applied to an omnidirectional sound source to create binaural sound channels. By using computed HRTFs for the "average" human head, and convolving the proper HRTF with the sound source—one can derive left and right channels for the sound.

Although little research has been conducted on the effects of micro-gravity on hearing, this information could be invaluable in a variety of applications. Medically, it could help to unravel how the human body becomes so disoriented in micro-gravity as to experience space sickness. Also, more realistic simulators that incorporate the audio localization distortions due to micro-gravity could be built to better train astronauts. As a final example, spacecraft and space station designers could carefully select the locations of sound-producing equipment to create a "sound landscape" that itself provides orientation clues.

Even if it is found that sound localization is not impaired in micro-gravity, this research could still be beneficial. Since the senses of touch and sight are readily confused by weightlessness, perhaps sound localization grows to prominence as a tool for assessing orientation in micro-gravity. In this manner, sound clues could be used to help astronauts regain their orientation in micro-gravity more quickly.

METHODS AND MATERIALS:

Instruments

Two laptop computers (one Dell Latitude 166CP, and one Apple Powerbook G3. Both running version of Linux) were brought on the airplane for testing purposes—one for each experimenter. Each had pre-recorded binaural sounds for each possible position that was tested. Outputting the sound from the laptop was a custom piece of software written exclusively for this test—the testing software performed the test on the human operator as described below.

Ideally two identical laptops would of been used, but due to sponsorship problems, only one laptop could be borrowed for the experiment. (Steve Chazin from Apple Computer provided one Macintosh G3 Powerbook for this experiment, and the Dell Latitude is Raffi Krikorian's personal laptop.)

Since it would be non-ideal to have two completely different laptops, as that would require more than one administration method and require two different testing packages to be authored (due to dissimilar ways of accessing the mouse and sound resources), the decision was made to install Linux on both laptops. RedHat 5.2 based on kernel version 2.2.3-5 was installed on the Dell, and Linux-PPC based on kernel version 2.2.1 was installed on the G3. Using Linux, the mouse can be accessed via the same client code using the GPM mouse handler. Unfortunately the operating system's sound interface was still non-standard between the laptops, but by using PERL scripts a "standard" interface was achieved.

To hear the sounds being presented by the testing program, two pairs of Sennheiser HMEC 200-IIIS active noise canceling headphones were brought aboard. These headphones are the ear covering type so as to provide some immunity from ambient noise (another control) and some safety to the human using them (headphones that require one to have the ear piece inserted and held by the ear seems too dangerous to use in the chaotic environment inside the KC-135a). Originally, it was planned to switch the active noise cancellation on, but after some discussion it was decided that the "anti-noise" produced by the feedback loop may disturb the sound localization mechanism as sound localization is based on frequency and time delay transformations.

Inflight Procedures

The subject's ability to localize sound was tested along the vertical and horizontal planes about the head. Each experimenter was able to run his or her own experiment (with the aid of a spotter to help safely orient the experimenter before the 2G portion of the flight), thereby allowing two simultaneous experiments to occur on board.

Localization tests were performed inflight. These tests attempted to discern how absolute sound localization accuracy is affected in micro-gravity. In other words, how accurately a subject can determine where exactly a sound is coming from. This strategy was supposed to enable us to pinpoint where the test subject perceives a sound loci to be (not necessarily where it actually is). This will be incredibly useful to determine whether the center of the audible field has shifted.

Each test was performed multiple times by different subjects in zero-G, and 1-G. We chose this testing suite because it gives us a broad picture of the human ability to localize sound (both accuracy and precision) across a large portion of the auditory field. The tests were not conducted for sounds coming from "behind" the head, because spatial hearing tests have shown that the human sound localization ability for these regions is extremely poor, hence accuracy data would not be reliable.

To minimize development time, the testing software was authored in Java to allow us to simply take the code and run it on both machines. There are subtle differences on the threading system between the two operating systems (even though they are both Linux systems), but once this difference exposed itself, it was relatively easy to make changes to the Java code so it ran properly on both machines without encountering a threading deadlock. Granted, the Java software needs to use the Java Native Interface to access the GPM code, but this was relatively easy as both Linuxes handled this exactly the same.

The testing software was composed of three execution threads. The first monitored mouse inputs, the second managed the sound resource of the computer, and the third monitored the experiment. Once the experimenter predicted the zero-gravity session was about to start (after experiencing one or two parabolas, it was easy to determine when zero-gravity was about to occur by listening to the activity of the KC-135a's engines), he was required to double click on the mouse to signal the beginning of a "run".

The double click event caused the managing thread to randomly select whether or not to perform a vertical sound localization test or a horizontal test (this random selection is slightly biased toward vertical tests as the hypothesis did predict a change in sound localization in the vertical plane and little to none in the horizontal). After choosing one, the managing thread asks the sound resource thread to notify the user which exam will be performed (this is done by simply playing back a previously recorded audio file of a voice saying "horizontal a-test", or "vertical p-test", or other similar files) while simultaneously locking the mouse thread to prevent any mouse events to be propagated.

Once the audio process is completed, the manager unlocks the mouse thread and then randomly chooses from the set of sounds available to test a binaural file to play. It plays this file and waits for mouse input. Once mouse input has been received, the manager logs the input along with date stamps indicating the time at which the sound was played and the time a mouse input was received and then plays another randomly selected binaural sound.

This testing sequence proceeded in a loop until the manager thread detects a double click mouse event. A double click in the middle of the run signals the computer to stop testing procedures as the zero-gravity portion of the parabola is ended and the two-g pull up is begun. Upon receiving this event, the manager thread locks the audio thread and pauses itself until the next double click which signals the beginning of the next run.

The data logged was minimal. No processing was performed by the testing program. All the processing would be completed during data analysis. The procedure for data logging was to open a file with the filename being the current time (in seconds from the epoch), write the time stamp, write whether the test is horizontal or vertical, write the binaural sound file's name, and then write the mouse click event.

All the data was analyzed using PERL scripts to extract the relevant information from the data logged file and present it in a readable format.

There are 328 data points logged among the three testers between the two days of flight (ideally there should of been more data, however one experimenter became extremely motion sick during the flight and could not provide useful data). Most other human factors experimenters aboard the KC-135 only tested one subject at a time thereby only getting two person's worth of data. Getting three people's data points lends more statistical relevance to the results.

The testing code was slightly biased, performing more vertical tests than horizontal tests. This bias reveals itself under examination of the number of each type of test. Out of the 328 zero-g data points, 211 (64.3%) of these were vertical tests and 117 (35.7%) were horizontal tests. Of the 450 one-g data points, 246 (54.7%) were vertical, and 204 were horizontal (45.3%).

Right/Wrong Percentages is a simple first pass analysis test which was performed on the data files. It is a calculation of the right/wrong percentages, ie—in what percentage of the points did the computer play a sound coming from the right and the user then responded that the sound was coming from the right. Since the data on which file is played and which mouse button is pressed are both recorded in the data files, simply parsing all the data and summing up the responses provided this information.

RESULTS:

Preliminary data analysis has revealed three noticeable trends. First, in one-g the probability of hearing a sound from the left versus the right is approximately the same (as it should be if the test subject does not have damaged hearing). Second, the data indicate that the ability to localize sound horizontally unevenly diminished in micro-g. And third, in micro-gravity the ability to vertically localize sound has "shifted''. Sounds coming from below the horizontal plane are identified as such more often than in 1-g.

It should be noted that this type of analysis provides no insight into this data. For example, it is possible for the right/wrong percentage to stay the same but have the distribution of the correct values be completely different. This analysis is useful as a preliminary review of the data, but a more comprehensive analysis is required.

To better analyze the data, distribution graphs of the data needed to be created. The problem with simple right/wrong percentages is that they do not tell the reader how well the tester can localize at any given angle. This information is needed to obtain a full picture of the data. A distribution graph reveals the percentage of right answers (the vertical axes) over a certain degree range (the horizontal axes).

These graphs help localize the center of the audible field. When the sound is being played more toward the tester's sound center, the tester will not be able to respond with certainty where the sound is coming from. This should cause a significant ``dip'' in the distribution graph helping locate the center of the tester's sound field.

Distribution graphs revealed changes in the accuracy of sound localization The sound localization mechanism does get confused in micro-gravity as evidenced by graphs with multiple peaks. However for all the graphs (except for one experimenter's), the percentages remain above 50% which suggests that the tester is confident on location of the sound source.

This one experimenter's data also showed that right side percentages dropped considerably in micro-gravity. The only explanation that can be given for this is that the KC-135a's engines were to the right of that experimenter during the entire flight. Horizontal sound localization is dependent on the perceived relative volumes of the left and right sounds—with the plane's engines slightly disturbing the observed sound in the right ear, this experimenter may have been having problems compensating for the noise.

For the one-g data, the center of the sound field can be determined relatively easily. All of the data sets have a major drop around negative five degrees which describes the perceived center to around that point. One experimenter's data seem to have another drop around positive 42 degrees, but that is due to there being only three data points in that vicinity, one of which he answered incorrectly.

Determining the center of the sound field is considerably more difficult in micro-gravity. When trying to centralize the drops in the distribution plots, it seems as if the center stays relatively near zero degrees. This is consistent with the prediction that sound localization will not change significantly in micro-gravity.

The vertical distribution plots created are also of great interest. There is no conclusive evidence that the center of the sound field shifted vertically, but there may be "hints'' of this effect found in the data.

One major point that should be considered is that the distribution peaks are centered around (if not below) the 50% line. This heavily suggests that the testers were simply guessing about the origin of the sound.

The center of the one-g data points seems to be near zero degrees (if not a little negative), just like the horizontal one-g points. When trying to find the center of the vertical sound field in micro-gravity, it seems as though it is still centered at zero or perhaps slightly positive of zero. This does hold consistent with the tester's simply guessing instead of actually localizing sound.

The cumulative data are very consistent with the results outlined above. In both one-g and micro-g, the horizontal plots seem to have their confusion zones centered around zero degrees. And again, the vertical plots seem to be both centered around zero degrees. But it must be noted that the data is centered at a lower percentage than the horizontal distributions; this, as stated above, states that the tester was simply guessing instead of localizing the sound.

DISCUSSION:

The data presented in this paper are far from conclusive. The first major problem with this experiment was that all the testers knew the hypothesis before performing the experiment.

Ideally, all human subjects should not know the predicted results when performing an experiment. These types of tests should be done in a blind or double-blind manner.

The second problem is with the experiment itself. Localization in the vertical direction is very hard for humans to do; evolutionarily and developmentally, horizontal sound localization is prevalent. This problem manifests itself in the vertical localization distribution graphs. The percentage center in these graphs are considerably lower than the percentage center in the horizontal distribution graphs.

Ignoring these two points, the center of the auditory field does seem to have shifted slightly positive. The reasoning behind the shift is not conclusive, however; it may be due to experimental error, or it may be a real shift due to the micro-gravity environment.

CONCLUSION:

Future research is necessary to make a conclusive statement. One recommended testing method would be to use true spatial audio headphones (multiple channels with the speakers mounted in a spatial configuration) instead of the binaural format. Research aboard the Space Shuttle with trained astronauts as the subjects may also be extremely useful. The combination of using people who are not trained for a weightless environment and the extremely disorientating and fluctuating gravity situation aboard the KC-135a makes the data slightly questionable.

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99EO3212
99EO3219 to 99EO3220
99EO3280

VIDEO: provided

20000025642

521/51 IT.R.

434563

TITLE:
Undergraduate Program Flights - NIMBLE: a Non-Invasive Microgravity Biomedical Life-Sciences Experiment

FLIGHT DATES:
March 26-27, 1999

PRINCIPAL INVESTIGATORS:

Christopher Carr, Massachusetts Institute of Technology
Elizabeth Walker, Massachusetts Institute of Technology
David Pinson, Massachusetts Institute of Technology

NASA Photo: 99EO3236

GOAL:

To evaluate the Non-Invasive Microgravity Biomedical Life -Sciences Experiment (NIMBLE) hardware during KC-135 parabolic flight.

OBJECTIVES:

The objectives of this project are to verify the effects of micro- and hypergravity on the heart rate on humans to test the usability of the wearable computer-based bio-monitoring system. Passively collected pulse-oximetry and ECG data will be used to test the effects of micro-and hypergravity on the heart rate of humans. A workload task, which requires the flight crew to integrate information from the external and internal (on-screen) environments, will be used in conjunction with a subjective evaluation to test the hypothesis of system usability.

INTRODUCTION:

Long-term bio-monitoring of astronauts (onboard the International Space Station, or other long-term manned space platforms) has the potential to further our understanding of human adaptation to the space environment, and may lead to health benefits through contributions to our understanding of basic human biological mechanisms. In addition, "human-centered" monitoring of astronauts can contribute to ensuring a safe environment via continuous monitoring. Astronaut health is crucial to mission success, therefore the monitoring of crew health is an important aspect of mission execution.

Monitoring devices can be bulky, uncomfortable and even dangerous if they are invasive or encumbering. The availability of a non-invasive and compact monitoring device would not only increase safety, but also improve the productivity of astronauts if it allows greater mobility. Because of the space and weight limitations on every mission, the ability for a system to perform multiple tasks in addition to bio-monitoring would be a huge advantage.

METHODS AND MATERIALS:

A flexible "human-centered" wearable computer-based system for astronauts that serves as a bio-monitoring device and multi-functional tool was constructed and tested in microgravity, 1G, and 1.8G environments using ground testing and flight testing on board the NASA KC-135A aircraft. Electrocardiogram (ECG) and blood pulse-oximetry data was non-invasively monitored to determine the effects of microgravity and hypergravity on the human heart rate, and two human factors workload tests were performed during all phases of flight. One test evaluated the ability of the flight crew to memorize a group of letters on the head-mounted display of the wearable computer and identify a letter in that group from a second group of letters. The second test compared the use of the wearable computer as a checklist to the use of a typical paper checklist for performing a series of procedures.

RESULTS:

Preliminary analysis suggests that the heart rate data collected is not medically useful due to several factors including the excitement of the subjects and the effects of anti-motion sickness drugs ingested by the subjects prior to flight. However, cyclic effects on heart rate during repeated parabolas were noticeable. Average memorization times and identification time for the first human factors tests were similar in all three gravitational environments. Estimated completion time for a checklist of 12 tasks was found to be about 10% faster in the 0-g and 2-g environments but only slightly faster in the 1-g environment.

DISCUSSION/CONCLUSIONS:

The "human centered" wearable-computer paradigm has the potential to greatly increase the mobility of astronauts performing tasks, and can be used by astronauts to provide, for example, training on demand, experimental protocol, equipment maintenance procedures, equipment troubleshooting guidelines, and checklists. In addition, such a system has the potential to provide a method for long-term bio-monitoring of astronauts and non-astronauts alike.

PHOTOGRAPHS:

99EO3185 to 99EO3186
99EO3194
99EO3216 to 99EO3217
99EO3233
99EO3235 to 99EO3236
99EO3266 to 99EO3267
99EO3269
99EO3278
99EO3311
99EO3314
99EO3317

VIDEO: provided

20000025644

TITLE:
Undergraduate Program Flights - Correlation of Microgravity Simulation through Fitt's Law

522/53

FLIGHT DATES:
March 26 -27, 1999

434564

PRINCIPAL INVESTIGATORS:
Dan Bendor, University of Maryland
Eric Fiterman, University of Maryland
Cristin Smith, University of Maryland
Larry Johnson, University of Maryland

NASA Photo: 99EO3205

GOAL:

To correlate upper arm mobility in microgravity, neutral buoyancy, and normal 1-g conditions.

INTRODUCTION:

Our project consists of a correlation study of upper arm mobility in microgravity, neutral buoyancy, and normal 1-g conditions. In order to contrast the different environments, a design to collect data based on Fitt's Law will be used as a measure of coordination.

METHODS AND MATERIALS:

Test subjects must press buttons on a taskboard, with buttons being of different sizes and distances apart. There will be a linear trend where movement time increases with a decrease in button size and an increase in button distance. We will compare these trend lines to correlate upper arm mobility in microgravity (in the KC-135A), neutral buoyancy, and normal 1-g conditions. Different test subjects and constraint systems will be used in order to increase the data collected.

RESULTS:

Our data collected to this point has only been in the KC-135A microgravity environment, and thus we can only make a preliminary guess as to how microgravity compares to 1-g and neutral buoyancy conditions. When using the hand and foot restraint system, a person is well strapped in and his/her body does not move. Thus the movement times will be very similar in all three environments. However, movement times will most likely be the slowest in microgravity when using only the single hand restraint or only the foot restraint. In 1-g normal conditions, a constraint system does not affect movement times, but when you are weightless, your movement time is slowed down by the disorientation of your body. Your body drifts away from the taskboard, and is only kept nearby depending on how good your restraint system is. A foot restraint system turned out to be superior to the single hand restraint system (an EVA handrail). We predict that the movement times in the neutral buoyancy simulation will be a little faster than the microgravity simulation when using only one constraint system, because the drag of the water will stabilize the drifting of the body caused by weightlessness. However, the drag will slow upper arm mobility to some degree, and so we will see movement times being the slowest in this environment when the test subject is using both constraint systems.

DISCUSSION/CONCLUSION:

After we finish our data collection, we will determine quantitatively how much microgravity and neutral buoyancy change the upper arm mobility one experiences in normal 1-g conditions.

PHOTOGRAPHS:

99EO3176 to 99EO3179
99EO3205
99EO3281 to 99EO3285

VIDEO: provided

20000025645

TITLE:
Development of a Whole Blood Staining Device for use during Space Shuttle Flights

523/52

434565

FLIGHT DATE:
April 20, 1999

PRINCIPAL INVESTIGATOR:
Clarence F. Sams, NASA/Johnson Space Center

CO-INVESTIGATORS:
Brian E. Crucian, Wyle Life Sciences
Vaughan L. Clift, Lockheed Martin, Inc.
Ellen M. Meinelt, Wyle Life Sciences

NASA Photo: 99EO4612

GOAL:

To evaluate the whole blood staining device (WBSD) during microgravity aboard the KC-135.

INTRODUCTION:

Exposure to microgravity during space flight results in profound physiologic changes. Numerous studies have shown changes in circulating populations of peripheral blood immune cells immediately after space flight. It is currently unknown if these changes result from exposure to microgravity or are caused by the stress of reentry and readaptation to gravity.

METHODS AND MATERIALS:

We have developed the whole blood staining device as a system for the staining of whole blood collected during space flight for subsequent flow cytometric analysis. This device contains all liquids to address safety issues concerned with space flight and also moves the cells through the staining, lyse/fixation and dilution steps.

In order to test the fidelity of this procedure in a true microgravity environment, WBSD staining experiments were flown aboard a KC-135 aircraft. This aircraft is used by NASA to simulate microgravity for experimentation and training purposes. The KC-135 is a modified cargo jet aircraft which is flown in a series of upward and downward arcs (parabolas). During the top of the parabola a period of free fall or weightlessness is achieved which essentially mimics the effects of space flight. The period of weightlessness in each parabola is 20-25 seconds, and approximately 40 parabolas are flown per flight.

RESULTS:

Data from flow cytometric analysis of samples stained in the WBSD was found to be comparable to data from samples stained by the conventional methods. Cells stained with the WBSD remain stable in the device for up to 14 days. The necessary manipulations required to use the device were tested on the KC-135 aircraft during the reduced gravity segment of parabolic flight.

On a previous flight, we tested the necessary manipulations to use the device during microgravity. During the most recent flight (April 20, 1999), we tested the effectiveness of the staining, mixing and lysing in microgravity by performing a complete blood immunophenotype analysis. The requirements to physically manipulate the device were altered compared to those required in normal gravity. In particular, the absence of gravity caused altered fluid dynamics in the device chambers. Basically, this meant that the fluids tended to float as opposed to gathering at the bottom of the chamber. This effect was found to not modify the white blood cell staining or lysing of the red blood cells, however it was necessary to ensure complete mixing of the reagents at each step. Flow cytometic analysis of these samples revealed excellent separation between the populations and no

abnormal staining results were seen. The KC-135 results confirmed the ease and utility of this system for whole blood staining during space flight.

DISCUSSION/CONCLUSIONS:

With the WBSD immunophenotype analysis can be performed at various time points for the duration of an entire Shuttle flight. In addition, this device has significant terrestrial applications for rapid and easy immunofluorescence labeling of whole blood in remote and isolated locations where immediate access to specialized equipment and skilled laboratory personnel may not be available. The WBSD provides a simple mechanism to design specific immunophenotyping tests for use by nontechnical personnel at bedside or in field locations.

PHOTOGRAPHS:

99EO4600
99EO4611 to 99EO4614

VIDEO: provided

20000025647

TITLE:
"Fly High" Program - Human Interface Demonstration

524/54
434566

FLIGHT DATES:
April 20-21, 1999

INVESTIGATORS:
Amanda Grubbs, Longview High School, Longview, Texas
Jason Mayes, Longview High School, Longview, Texas
Bryan Lawson, Longview High School, Longview, Texas
Kirsten Welge, Longview High School, Longview, Texas
Don Robinett, Longview High School, Longview, Texas
Ruth Ann Pope, Longview High School, Longview, Texas
Alicia Moore, Longview High School, Longview, Texas
Suzette Shivers, Longview High School, Longview, Texas
Rachel Beene, Longview High School, Longview, Texas
Michel Zountendam, Longview High School, Longview, Texas
Cherry Moore, Longview High School, Longview, Texas
Jessie Roberts, Longview High School, Longview, Texas

MENTORS:
Jeff Fox, NASA/Johnson Space Center
Harold Robertson, NASA/Johnson Space Center

NASA Photo: 99E04592

GOAL:

The goal of this experiment was to determine which of the four Interface Control Devices (ICDs) performed the best in a zero-G environment, based on accuracy, maneuverability, and comfort.

OBJECTIVE:

The objective of the flight tests in the KC-135 and the ground tests in the X-38/CRV Remote Cockpit Van were to evaluate the four different ICDs: Smart Cat Touchpad, Microsoft SideWinder 3D-Pro Joystick, Microsoft SideWinder Gamepad, and the Logitech Trackman Marble (Optical Trackball). The major design issues that were addressed during this experiment were the ability to maneuver the ICDs, how easily they handled blind operations, and comfort in micro-gravity.

INTRODUCTION:

The X-38 Project Office at Johnson Space Center is currently creating the Crew Return Vehicle (CRV) The CRV is being designed as a rescue vehicle that will be docked at the new International Space Station, to be used in the event of an emergency. The Longview High School branch of the Texas Fly High Class of '99 is helping with the design of the Input Control Devices (ICDs) to be used in the CRV. The CRV will be almost completely automated with a few crew control functions and selected manual backup functions. As part of the development of the CRV, the X-38 ICD experiment conducted two flight evaluations and a series of ground evaluations of the selected ICDs. Our team designed a bracket that held a laptop above the seat where the test conductor reclined. Each ICD was anchored to the armrest, also designed by our team members, by means of velcro. The students on the team conducted the test, as well as various NASA personnel. The mentor from the X-38 Project, a sponsor, or a journalist stood nearby and evaluated the test. Another student acted as a test monitor, and helped with different functions, setups, and performances.

METHODS AND MATERIALS:

In order to test the accuracy of the controllers, we employed a program based upon the original Anti-Ballistic Missile game - subjects had to target a 'missile' as it appeared at the top of the screen and click upon it to eliminate it before the dot reached the bottom of the screen. Each subject performed ten rounds on each device, with the number of missiles onscreen at any given time increasing by one per round (i.e., first round = one dot onscreen at a time; tenth round = ten dots onscreen at a time). The percent accuracy was tabulated per round by dividing the number of missiles hit by the number of misses (clicks without hitting a missile).

This experiment also required that a bracket be designed to secure the computer monitor for the duration of this experiment - several of our team members collaborated to construct such a bracket. These same members also designed an armrest to stabilize the

ICDs once the need become apparent later on in the program. To fasten down the controllers and thus provide a stable apparatus, we attached velcro straps to each controller and the armrest, as well as securing the subject's arm to the armrest with a velcro strap.

RESULTS:

For the data analysis, we classified the data into two sections, subjective and objective. Within the objective segment was the data obtained by the scores received by the test subjects by the program; the subjective portion was collected by means of questionnaires filled out by ground and air test subjects.

Objective Conclusions

The overwhelming majority of the objective data from both the ground and the flights confirmed that the Logitech Trackman Marble surpassed the other three ICDs in respect to accuracy and maneuverability. Interestingly enough, this result was the converse of an earlier experiment performed by the X-38 Office. However, we believe this differing result was obtained due to our use of velcro and an armrest to secure the ICD, whereas the previous experiment neglected to adequately secure the optical trackball.

Subjective Conclusions

The subjective data portrays a different image. The questionnaire responses lean in the direction of the joystick, which seems rather odd, until one takes into account the many games and flight simulators that utilize joysticks. All three groups on the ground (the ground crew, off-duty flyers, and the NASA personnel test subjects) claimed that the joystick was more comfortable, exerted less stress on the hand, and even maneuvered better than the other ICDs, despite the data garnered from the test scores.

DISCUSSION:

Certainly, the joystick does have its advantages. The pilots who will in all likelihood be flying the CRV will have had much more training with a joystick than the trackball; however, one must not ignore the results of the objective data, which point to the optical trackball as the best ICD for the task presented. In addition, several of the test subjects stated that although the trackball was more "intuitive", they preferred the joystick. There are some gray areas. On average, the trackball was surpassed by another ICD during the first two rounds of the program; it might be beneficial to discover why. Perhaps the joystick is better for simple maneuvering, while the trackball is best for quick, precise movements with lots of distraction. One must also take into account the possible disadvantages of the trackball. The person selected to guide the CRV down to Earth will, in all probability, be under a great deal of stress, which often manifests itself through trembling hands. This could be a severe detriment to this ICD, since the trackball registers all movements of the hand as 'commands'. In addition, the proper ICD may vary depending upon the task selected for the pilot of the CRV. If the task is to control the movement, descent, yaw, and so forth (actually 'fly' the vehicle), the best ICD for the task may be different from the ICD best suited to a computer guided descent which requires

only information and assent from the pilot. Our testing pool was also rather small, especially in the air, where half of our crew suffered from severe motion sickness; personal differences in the able flight crew could account for some of the gap between performances of the ICDs. It would be worthwhile to explore this idea as well.

CONCLUSION:

Thus, from our preliminary conclusions, we have ascertained that the trackball would probably be the most efficient controller for the CRV, due to the objective results dealing with maneuverability and accuracy. Despite the lean towards the trackball in the subjective questionnaires, we believe that the objective, unbiased data is probably the best estimate of the most suitable ICD.

PHOTOGRAPHS:

99EO4580
99EO4582 to 99EO4584
99EO4592
99EO4594 to 99EO4595
99EO4600
99EO4624 to 99EO4625
99EO4786 to 99EO4787
99EO4789
99EO4796
99EO4798
99EO4799
99EO4801
99EO4804
99EO4808 to 99EO4809
99EO4811
99EO4817 to 99EO4818

VIDEO: provided

2000025649

TITLE:
"Fly High" Program - The Effects of Microgravity on the Human Body

FLIGHT DATES:
April 20-21, 1999

525/52
434567

PRINCIPAL INVESTIGATORS:
Kris Wood, Chisum High School, Paris, Texas
Davin Bradberry, Chisum High School, Paris, Texas
Cari Cassell, Pittsburg High School, Pittsburg, Texas

CO-INVESTIGATORS:
Matt Cheshier, Pittsburg High School, Pittsburg, Texas
John Denney, Pittsburg High School, Pittsburg, Texas
Jason Hubbard, Pittsburg High School, Pittsburg, Texas
Crystal Edwards, Satillo High School, Satillo, Texas
Ashley James, Satillo High School, Satillo, Texas
Kelli Brewer, Satillo High School, Satillo, Texas
Crystal Floyd, Satillo High School, Satillo, Texas

MENTOR:
Marlo Graves, United Space Alliance

NASA Photo: 99EO4601

GOALS:

To measure blood pressure, pulse, and reflexes in a microgravity environment and then compare results to a preflight base line.

INTRODUCTION:

This experiment was a collaborative effort undertaken by several schools in the Region 8 Service Center area.

METHODS AND MATERIALS:

Subjects
Five subjects participated in the experiments aboard the KC-135.

Instruments
Blood Pressure Cuff
Reflex Hammer

Procedures
Standard Blood Pressure and Reflex Measuring Techniques

RESULTS:

The inflight results appear to be inconclusive. Some of the data collected aboard the KC-135 are shown in the table below:

Subject: 1

Day	Parabola	Systolic Pressure	Diastolic Pressure
4/21/99	6	120	75
	7	120	80
	8	115	75
	9	115	60
	31	115	60
	32	115	60
	33	120	70

Base Line Blood Pressure: 120/75 *

Subject: 2

Day	Parabola	Systolic Pressure	Diastolic Pressure
4/20/99	5	120	80
	6	130	64

Base Line Blood Pressure: 120/80 *

* Denotes blood pressure in normal gravity after taking anti-nausea medication.

Reflexes were measured qualitatively, meaning we had no set apparatus to measure reflexes. Reflexes were determined to be looser in microgravity.

Subject 1's pulse measurement was taken at 70 beats per minute during flight

DISCUSSION/CONCLUSION:

As seen in the chart above, there is no clear pattern to our blood pressure measurements. Due to the uniqueness of the environment, subjects becoming ill, and our blood pressure cuff breaking on the 20th parabola, we were unable to take enough measurements to come to a definitive conclusion. With the techniques learned from the first two flights, later experiments could be conducted with better precision and yield more results. The degree to which the test subjects failed to adapt to the microgravity environment limited our data gathering both in quality and quantity.

PHOTOGRAPHS:

99EO4579
99EO4585 to 99EO4591
99EO4599
99EO4600 to 99EO4601
99EO4618
99EO4620 to 99EO4622
99EO4626
99EO4791
99EO4797
99EO4800
99EO4803
99EO4805 to 99EO4806

VIDEO: provided

20000025651

526/52

434571

TITLE:
"Fly High" Program - Development of Motion Sickness and Postural Ataxia in a Reduced Gravity Environment

FLIGHT DATES:
April 22-23, 1999

INVESTIGATORS:

Christie Parker, New Caney High School, New Caney, Texas
Fernando Pena., New Caney High School, New Caney, Texas
Vincent Shepard, New Caney High School, New Caney, Texas
Kristy Yager, New Caney High School, New Caney, Texas
Amy Guidry, New Caney High School, New Caney, Texas
Courtney Hobbs, New Caney High School, New Caney, Texas
Anthony Kahl, New Caney High School, New Caney, Texas
Clint Moore, New Caney High School, New Caney, Texas
Jennifer Nielson, New Caney High School, New Caney, Texas
Phillip Pena, New Caney High School, New Caney, Texas
Austin Scheible, New Caney High School, New Caney, Texas
Craig Smith, New Caney High School, New Caney, Texas

MENTOR:

Natalia Banasik, United Space Alliance

NASA Photo:99EO4949

GOAL:

Investigators, listed above, will attempt to determine which conditions, if any, will reduce or alleviate the effects of motion sickness and postural ataxia in a reduced gravity environment.

INTRODUCTION:

Motion sickness and postural ataxia often present a problem for astronauts and cosmonauts on missions, causing delays in schedule, and occasionally causing a mission to be actually inefficient. As evidence provided by our mentor, Mrs. Banasik indicates, 40-70% of astronauts will experience in-flight neurovestibular effects. These include postural illusions, tumbling sensations, nystagmus, vertigo, and space motion sickness: pallor, cold sweating, nausea or vomiting. These symptoms usually appear early in the course of the flight, and disappear or subside within a few days.

Because the effects of motion sickness can inhibit the progress of astronauts in regard to their experiments, the original reason for launching these costly missions can be delayed or essentially lost. Thus, it becomes evident that further research into preventing or alleviating the effects of motion sickness is necessary, and would be highly beneficial to the productivity of space missions. Since the field of subjects that have actually flown on such space missions is limited, and because the onset of motion sickness/postural ataxia is almost immediate upon reaching zero-gravity, experiments using the parabolic flight of the KC-135 can be used to generate data related to this condition.

METHODS AND MATERIALS:

Subjects
Subject/flyers listed above will hereafter be referred to by assigned numbers.

Instruments
Straps were utilized to hold observers' feet in a secure position. A microcassette tape recorder was used to record subject comments.

Procedure
One member of each pair of subjects (101, 104 and 102, 103) remained stationary, and assisted the observer in completing several sets of rotations in the space of one parabola per experiment. The experiments are as follows:

Experiment 1: subject will rotate at approximately 15 rpms with eyes open
Experiment 2: subject will rotate at approximately 15 rpms with eyes closed
Experiment 3: subject will rotate at approximately 15 rpms with eyes open, shaking head in a "yes" motion
Experiment 4: subject will rotate at approximately 15 rpms with eyes open, moving head in a "no" motion

Between parabolas, the observer will record the data from the previous experiment.

RESULTS:

Flight one: subjects 102 and 103 were unable to retrieve any data due to extreme sickness experienced by first subject, as well as a failure in the tape recorder to record any data.
Flight two:

Subject 101: Test 1, run 1: mild nystagmus
Test 1, run 2: slight disorientation
Tests 2, run 1: no symptoms
Test 3, run 2: slightly flushed in color
Test 3, run 3: slight dizziness
Test 4, all runs: no symptoms
other data inconclusive as no experiment number was recorded in taping

Subject 104: became ill after a few parabolas, attempted to complete experiment later.

Subject 100: Test 1, all runs: no symptoms
Test 2, all runs: no symptoms
Test 4, run 1: no symptoms
Test 4, run 2: slight dizziness
Test 4, run 3: slight dizziness
Test 4, run 4: no symptoms
Test 3 not run, or recorded, due to loss of parabolas in subject 104's illness and absence.

DISCUSSION:

A series of ground experiments were run as baseline data for the experiment. The baseline data are currently being analyzed. Only preliminary observations can be made at this time.

CONCLUSION:

While dramatic differences in the results of the experiment were expected, based on motions onboard the aircraft and the results of baseline data, no clear correlation was found within the results. We are currently conducting further analysis of the data to find any underlying factors which may have influenced the results of this experiment.

PHOTOGRAPHS:

99EO4854
99EO4867 to 99EO4868
99EO4870 to 99EO4871
99EO4947 to 99EO4949
99EO4943
99EO4938
99EO4932 to 99EO4934

99EO4931
99EO4927
99EO4922 to 99EO4924

VIDEO: provided

TITLE:
"Fly High Program"- Night Cap Monitor

FLIGHT DATES:
April 22-23, 1999

PRINCIPAL INVESTIGATORS:

Miriam Dobbins, Van Alstyne High School, Van Alstyne, Texas
Rusty Dyer, Van Alstyne High School, Van Alstyne, Texas
Ashley Haddox, Van Alstyne High School, Van Alstyne, Texas
Heather Potter, Van Alstyne High School, Van Alstyne, Texas
Erin Taylor, Van Alstyne High School, Van Alstyne, Texas
Daniel Taylor, Van Alstyne High School, Van Alstyne, Texas
Lizabeth Sauer, Van Alstyne High School, Van Alstyne, Texas
Toni Butcher, Van Alstyne High School, Van Alstyne, Texas
Whitney Powers, Van Alstyne High School, Van Alstyne, Texas
Jessica Mosca, Van Alstyne High School, Van Alstyne, Texas
Criss Martin, Van Alstyne High School, Van Alstyne, Texas
Lindsey Williams, Van Alstyne High School, Van Alstyne, Texas

MENTOR:

Andrew Zarechnak, United Space Alliance

NASA Photo: 99EO4848

GOAL:

To measure head motion during micro-gravity as the experiment aboard the MIR did, to make the accelerometer more comfortable, and to make sure the accelerometer worked in micro-gravity are the goals of this investigation.

INTRODUCTION:

We are going to have two people flying each flight, one will be running the computers while the other is moving the mannequin head in back and forth motions to measure the head motion.

METHODS AND MATERIALS:

Mannequin (dummy) head, duct tape, 2 head motion accelerometer sensors, nightcap monitor, 2 Macintosh computers, stocking cap, velcro, metal platform, foam, paper, and pen.

Subject
mannequin head

Instruments
Macintosh Powerbook 180, Macintosh Powerbook 170, nightcap monitor with head motion accelerometer sensor.

Pre-flight Checklist:

1. All of the equipment that will not already be on the plane upon arrival will be carried in a bag, which will be taken off of the plane by the ground crew.
2. Ensure that the table is securely bolted to the floor of the plane. This is to prevent its coming loose during the flight and injuring any passengers.
3. Make sure that all the laptops to be used on the flight are on the plane.
4. Be certain that the laptops are both velcroed to the table and have bungee cord straps. The prop-up legs on the back of the laptop must stay up. Otherwise, securing the laptop down with velcro and bungee cords would be pointless. This is also to prevent them from coming loose and injuring any passengers or breaking on impact with the 'floor' of the plane, 'ceiling' of the plane, 'wall' of the plane, etc.
5. Ensure that the dummy head and sensor are on the plane.
6. Make certain that the dummy head can be secured with velcro to the table for take-off and landing. This will prevent the head from getting away from the flyer.
7. Be sure that the bungee cords holding the computer operator are secure and in place.
8. Back up nine volt batteries should be kept in a zippered pocket or bag which will be secured to the table.
9. Be sure that the bag holding the batteries, if a bag is being used versus a zipper pocket, that it is securely velcroed to the table within reach of the computer operator.

Post Micro-gravity:

1. NOTE: Following steps should be implemented after last test:
2. After the last tests have been carried out, Press <COMMAND><PERIOD> on both Powerbooks.
3. Turn off all Nightcap Head Monitors. Press <RETURN> 3 times to completely end the program.
4. Clean up any messes. Prepare to tell stories.

Procedure for Computers:

i.e.; operating lap tops, connecting the nightcap

NOTE: One laptop will be used for the flyer, and the other for the dummy head. The following procedure works for both of the laptops.

1. Plug computer into a power source, open the laptop and the flap on ;the back to the computer, and push the button on the right to turn on the computer.
2. Plug in the cable from the nightcap monitors to the right most port.
3. Plug in the cords, matching colors to the night cap monitor and the Macintosh adapter.
4. Once the computer has booted up, open the *Macintosh HD* icon, open the *Van Alstyne* folder, open N*ightcapf V10.4* under *Nightcapf* folder.
5. Follow directions on the system.
6. To mark the entry and departure of zero gravity, the computer operator will hit the space bars of the laptops and say, "MARK," to ensure that it will be picked up by video.

Procedure for Dummy/Nightcap:

i.e.; hooking up to lap tops, head movements

1. Hold your own head and dummy's head relatively steady throughout the period of micro-gravity.
2. Holding your own head steady, carry out the following sequence of movements with the dummy head
   a). Turn dummy head 90 degrees left in approximately .5 seconds.
   b). Hold steady 1 second
   c). Turn it right 180 degrees in approximately 1 second.
   d). Hold it steady 1 second.
   e). Turn it 90 degrees to the left.
   f). Hold it steady 1 second.

Repeat this sequence to the end of the arc.

3. To mark the entry and departure of zero gravity, the computer operator will hit the space bars of the laptops and say, "MARK," to ensure that it will be picked up by video.
4. Hold the heads steady, repeating task one.
5. Move the dummy head with both linear and angular accelerations and decelerations.
   (e.) Nod the head forward and backward.
   (f.) Angle head from side to side.

   After the sequence of four tasks is completed, repeat it on subsequent arcs. If there are forty arcs, the sequence will be repeated eight times.

Take Down Procedure:

i.e., disconnecting the Nightcap, shutting down program/laptops

1. To exit the Nightcap program hold down the apple key and press the period key.
2. Turn off the nightcap and press enter.
3. Disregard the next screen regarding a malfunction of the eye sensor.
4. Press okay.
5. Once the Nightcap program is closed, go under the Special menu and choose shut down.
6. Disconnect all cords and wrap them up neatly.
7. Close back access flap and shut the laptop.

Procedure to Retrieve Data:

1. Click on the *Van Alstyne* file folder.
2. Click on the *Nightcapf* file folder.
3. Open the *DataFiles* folder.
4. Find the most recent data and double click on the file picture next to it.
5. Two line graphs will appear.
6. To see Nightcap Data Summary, click on the window behind. It will be to the lower right of the screen. This will tell you how long the Nightcap recorded, how many minutes the subject was asleep, the percentage of being awake, and asleep. Ignore the R.E.M (Rapid Eye Movement) information, because this is not a part of the experiment being performed by the Van Alstyne High School Students.
7. To see the expanded graph, go to WINDOWS and hit EXPANDED GRAPH
8. Next go to UTILITIES and COPY GRAPH; close the program, then paste the graph into a blank POWERPOINT presentation. This is the only way that the graph will print.
9. When examining the graphs, the marks at the beginning and end of each parabola should appear as lines above the graph.
10. Information about the menu bar and the menu's:
    (j) FILE will give the option to close, open, print, and quit the program.
    (k) WINDOWS will give graphs of the Night/Summary Data, Expanded Graph View, and Vigilance Graphs.
    (l) GRAPH DISPLAY will show events, the graphs in military time, linear eye counts, line graphs, annotate on set, and predictions of awakenings.
    (m) NIGHTCAP will start the Nightcap, set the date and time, save Nightcap data, monitor the Nightcap, and erase Nightcap data.

RESULTS:

The data we collected printed out well, but the marks of the experiment were not visible. Using the videotape, we were able to correlate the data approximately with the printed graphs, except for the times when our view was blocked by NASA personnel standing in front of the camera.

- Hardware and Software Problems

  The laptops that we used were not resilient enough to withstand the rigors of 2G; the

hinge of one screen cracked within the first few 2G periods and that computer didn't work thereafter. The Nightcap program also did not mark at all while on the plane. It recorded data, but we are unable to definitively say where one parabola starts and another ends. It also would not allow us to print some of the graphs, which we thought were necessary.

- Sensor
  At the end of the graphs for the first flight day, there is a solid black line instead of data, and we believe that this was caused by the inner part of the sensor getting stuck to the side in 2G, causing it to give readings of intense constant motion instead of the movement pattern. The sensor does appear to record data, and getting stuck shouldn't be a problem in space, as long as the sensor is tested after takeoff to ensure that the sensor isn't stuck due to the increased gravity.
- Sleeping
  The participants who slept in both sensors while on the ground reported that the stocking cap was more comfortable than the headband mounted sensor, although neither was very conducive to deep sleep. They complained that the wires were hard and got wrapped around them and in their mouths while they were sleeping and that they woke up entangled in them, and also complained that the hat was hot. They also had trouble moving and turning over and said that it made the nape of their neck hurt to sleep on the sensor.

DISCUSSIONS/CONCLUSIONS:

- Personnel on the flight should be specifically instructed not to block the view of the video camera. We need to see all possible data.
- Improve the software program
  The software program needs a consistent marking system. It marked on the ground, but the shifts between ZeroG and 2G somehow affected it, and it never did in the air, and we were never sure why.
  The graphing portion of the program needs improvement. Several graphs could not be opened, and the process required to print them was impractical.
- Hardware glitches
  The computers were not resilient enough to withstand 2G. One computer went completely down, and the other had to be babied to make it work.
  The sensor should be redesigned. It needs a smaller package for the sake of comfort and should include a "stuck" signal and a procedure to correct it. It would also be beneficial to have a way of restraining the wires to prevent them from being wrapped around the wearer's neck while sleeping.
- The data and video should be correlated as soon as possible. It was somewhat difficult to recall the sequence of events later.

CONCLUSIONS:

While fraught with difficulties, we believe that our experiment was overall a success. Even with limited data, we are still reasonably sure that the head sensor does work and

that the program does accurately record the data from the sensor. The stocking cap is more comfortable than the headband and could benefit the astronauts by keeping their heads warm while they sleep. The Texas Fly High program is an excellent way to introduce students to the world of NASA and science careers. It was a wonderful experience, benefiting all involved, that we hope NASA will continue.

PHOTOGRAPHS:

99EO4829
99EO4848
99EO4860 to 99EO4864
99EO4867 to 99EO4868
99EO4944 to 99EO4945
99EO4942
99EO4939
99EO4930
99EO4928
99EO4922 to 99EO4924

VIDEO: provided

20000025655

434584

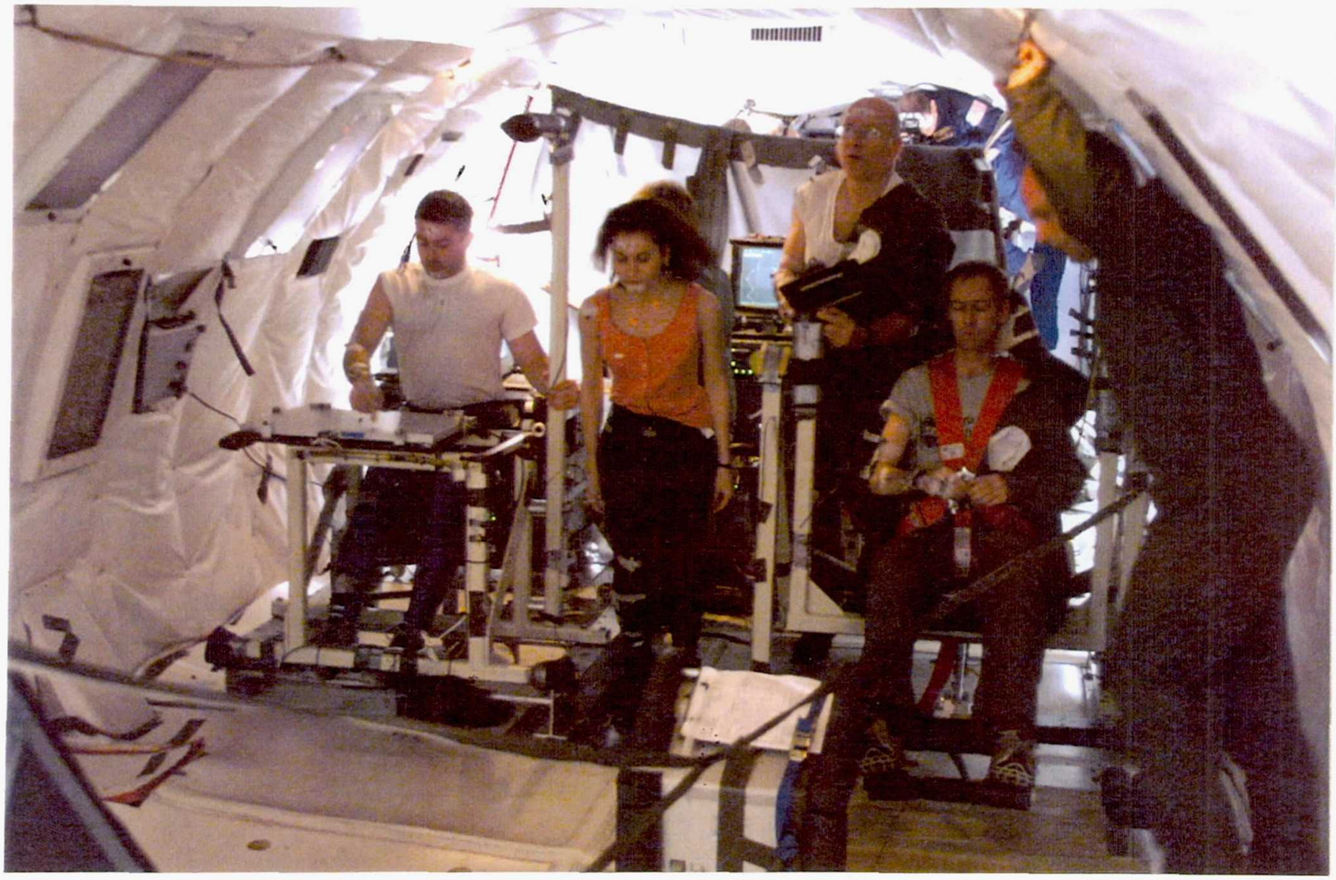
TITLE:
Adaptation of Reaching Movements in Artificial Gravity

FLIGHT DATES:
June 8-11, 1999

528/53

PRINCIPAL INVESTIGATORS

James R. Lackner, Ph.D., Brandies University
Paul DiZio, Ph.D., Brandies University



NASA Photo: 99EO6622

GOAL:

The goal of this experiment was to understand the role of cutaneous contact cues in control of reaching movements and posture.

OBJECTIVE:

The objective was to evaluate the force applied by the fingertip when it lands on a horizontal work surface at the end of a reaching movement aimed at a target on the surface.

INTRODUCTION:

We had found in 1 g stationary and rotating conditions that 1) fingertip shear forces generated when a reaching movement ends on a solid surface map directly onto shoulder position (DiZio, Landman & Lackner, 1999), and 2) variations in fingertip forces around a target correlate with reaching endpoint errors relative to the target and 3) subjects deprived of fingertip contact do not adapt their reaching movements to a rotating environment (Lackner & DiZio, 1994). The experiment of June 8-11 assessed in 0 g and 1.8 g 1) whether fingertip landing forces map onto arm position and 2) correlate with reaching endpoint errors.

METHODS AND MATERIALS:

Subjects

Eight subjects participated in this experiment. The subjects were all Graybiel Laboratory personnel who have extensive experience in parabolic flight. The same personnel alternately served as subjects and experimenters. All have passed the medical exams and physiological training required by the KC-135 office.

Instruments

The equipment for this experiment includes 1) a Northern Digital, Inc OPTOTRAK system for monitoring the three dimensional movements of small infrared markers placed on each subject's arm, head and torso and 2) a force plate mounted horizontally atop a table in front of a seated or standing subject on which visual targets can be projected.

Procedure

In this experiment subjects sit in a stationary chair with a flat table in front of them. When the subject presses a start button on the near edge of the table, a laser target appears on the table surface that he or she much reach out and touch. The subject's task is to look at the target then reach forward and place the finger on the target, at a natural, comfortable speed, in a natural manner. The computer emits a beep 3 seconds after finger liftoff to signal the subject to return to the start position, to await a new target. There are 16 targets, and one reach every 5 seconds is a leisurely pace. Thus, a subject completes 40 reaches in 0 g and 40 in 1.8 g during ten parabolas and 40 also in 1 g straight and level flight, allowing at least two reaches per target per g level, with plenty of time for rest if necessary. The second set of ten parabolas is done with the subject standing (feet anchored) instead of siting.

RESULTS:

Preliminary analysis indicates that complete data sets were collected from seven subjects, the eighth was lost when our computer crashed on the last day of flight because it was kicked by a member of another team. The results are 1) we have had complete success using the algorithms we had developed for separating force plate measurements into one component due to the fingertip forces and a second due to aircraft acceleration, 2) OPTOTRAK data indicate that reaching movement kinematics differ across the 0 g, 1.8 g and 1 g straight and level phases of flight, 3) force plate records indicate that fingertip contact forces were always too low (2-6 Newtons) to be mechanically supportive. It will take the rest of the summer for a complete analysis of the relationship between landing forces and fingertip/arm position.

DISCUSSION:

If the final results of these experiments show a positive relationship in 0 g then later experiments will test the hypothesis that fingertip contact facilitates adaptation of posture and movement to non-1 g environments.

CONCLUSION:

We will contact the KC-135 office around the end of August to plan for continuation of this experiment sometime around January, 2000.

REFERENCES:

DiZio P, Landman N, Lackner JR Fingertip contact forces map reaching endpoint. Society for Neuroscience Abstracts, 1999, In press.

Lackner, J.R. and DiZio, P. Rapid adaptation to Coriolis force perturbations of arm trajectory. Journal of Neurophysiology, 72(1):299-313, 1995.

PHOTOGRAPHS:

99EO6209
99EO6211
99EO6213 to 99EO6214
99EO6216 to 99EO6217
99EO6243 to 99EO6246
99EO6257 to 99EO6267
99EO6276 to 99EO6681
99EO6621 to 99EO6626
99EO6651 to 99EO6656

VIDEO:

KC-135 flights week of June 7-11, 1999, PMU: 11/49332

Videos available from Imagery and Publications Office (GS4), NASA/JSC.

2000025657

S29/53
434587

TITLE:
Effects of Background Force Level and Body Orientation on Arm Movement Control

FLIGHT DATES:
June 8-11, 1999

PRINCIPAL INVESTIGATORS
James R. Lackner, Ph.D., Brandies University
Paul DiZio, Ph.D., Brandies University

NASA Photo: 99EO6624

GOAL:

This experiment assessed how changing body orientation and background force level affect the reproduction of forearm movements between elbow joint angle endpoints practiced in 1 g.

OBJECTIVE:

The objective was to have subjects learn a simple, repeated forearm movement in 1 g and then measure their performance during exposure to 0g and 1.8g background force levels and novel body orientations.

INTRODUCTION:

Previous parabolic flight experiments (Fisk, Lackner & DiZio, 1992) showed that within one second after a transition to 0 g or 1.8 g background force subjects can reproduce a pattern of rhythmic forearm flexion-extension movements that they had learned in a 1 g environment. Our last set of parabolic flight experiments (6/98) showed that vestibular information about the force background is not necessary for this type of compensation, because a subject lacking vestibular function was as invariant in performance across g-levels as normal subjects. Thus, we hypothesized that somatic mechanoreceptors provide cues about the gravitational loads that are automatically compensated. We tested this by observing a deafferented subject and fully sensate control subjects attempting to produce a constant pattern of arm movement while passively placed in different body orientations, in 0 g, 1 g and 1.8 g.

METHODS AND MATERIALS:

Subjects

Seven subjects participated in this experiment. Six subjects were either members of the Graybiel laboratory or scientific colleagues. The seventh subject was an individual who has lived for the past 26 years with a sensory neuropathy depriving him below the neck of proprioception and cutaneous contact cues. All subjects had passed the medical exams and physiological training required by the KC-135 office.

Instruments

The equipment for this experiment includes 1) a Northern Digital, Inc OPTOTRAK system for monitoring the three dimensional movements of the subject's arm and 2) a chair with a contoured seat that could hold the subject comfortably in an upright or 45 ° pitched, feet up, position.

Procedure

The experiment was divided into a ground based training phase and a flight data collection phase. In both the training and data collection sessions, a trial consisted of ten cycles of forearm flexion-extension in a roughly vertical plane, between 145° and 110° elbow angle, with a one second stop at each endpoint, with eyes closed. The purpose of the ground based training was to make sure the subject could reproduce many trials of arm movements without deviating from the desired pattern, in a stereotyped manner, without looking at the arm. Ground based training was only done pre-flight in 1 g, in the upright chair condition. The experimenter monitoring the OPTOTRAK output relative to a reference arm configuration decided when training was adequate. We then tested the

seven subjects in 1 *g*, straight-and-level flight and also in both the 0 *g* or 1.8 *g* portions each parabola. In flight, subjects tried to repeat what they had practiced on the ground. During parabolas, a go signal was given in the middle of each 1.8 g phase and a stop signal in the middle of 0 g. In flight, each subject was tested in one set of parabolas with the chair upright and one set with it tilted 45° nose up, in balanced order.

RESULTS:

Complete data sets were collected from the deafferented subject and from four control subjects. The other two subjects were unable to complete the protocol because of motion sickness. Visual observation during the experiment revealed that the deafferented subject made larger arm positioning errors than both the controls and a subject without labyrinthine function whom we tested in June 1998. This supports the idea that non-vestibular touch pressure and kinesthetic cues are responsible for automatic adjustments that make posture and movement relatively flawless in novel force backgrounds. Performance appeared worse in the unpracticed posture, only in novel force backgrounds, for normal and deafferented subjects. This indicates errors of vestibular coding of body tilt in a non-1 g force background.

DISCUSSION:

Complete analysis of the data will be carried out over the summer. If they support the hypothesis that somatic mechanoreceptors are critical for automatic motor adjustments of arm movements to background force level then we will design new experiments investigating their role in stabilization of body posture and locomotion.

CONCLUSION:

At the beginning of September we will begin planning new parabolic flight experiments for January and June 2000.

REFERENCES:

Fisk, J., Lackner, J.R., and DiZio, P. Gravitoinertial force level influences arm movement control. Journal of Neurophysiology, 69(2):504-511, 1993.

PHOTOGRAPHS:

99EO6209
99EO6211
99EO6213 to 99EO6214
99EO6216 to 99EO6217
99EO6243 to 99EO6246
99EO6257 to 99EO6267
99EO6276 to 99EO6681

99EO6621 to 99EO6626
99EO6651 to 99EO6656

VIDEO:

KC-135 flights week of June 7-11, 1999, PMU: 11/49332

Videos available from Imagery and Publications Office (GS4), NASA/JSC.

2000025659

TITLE:
Magnetic Field Apparatus (MFA) Hardware Test

FLIGHT DATES:
June 8-10, 1999

530/35

434589

PRINCIPAL INVESTIGATORS
Ken Anderson, Bionetics

CO-INVESTIGATORS:
April Boody, Bionetics
Dave Reed, Bionetics
Chung Wang, Bionetics
Bob Stuckey, NASA/Johnson Space Center
Dave Cox, NASA/Kennedy Space Center

NASA Photo:99EO6638

GOAL:

To reduce or eliminate identified risks prior to spaceflight by answering questions that will aid in experiment and hardware design as well as postflight data processing.

OBJECTIVE:

1. Provide insight into water delivery in microgravity and determine optimal germination paper wetting for subsequent seed germination in microgravity;
2. Observe the behavior of water exposed to a strong localized magnetic field in microgravity; and
3. Simulate the flow of fixative (using water) through the hardware.

INTRODUCTION:

The Magnetic Field Apparatus (MFA) is a new piece of hardware slated to fly on the Space Shuttle in early 2001. MFA is designed to expose plant tissue to magnets in a microgravity environment, deliver water to the plant tissue, record photographic images of plant tissue, and deliver fixative to the plant tissue. Individual hardware that will be used for the MFA spaceflight experiment was tested on the KC-135 to identify potential problems and to verify current hardware design.

METHODS AND MATERIALS:

Experiment 1: Water Delivery and Paper for Seed Germination

Subjects: 2 subjects per flight day.

Instruments: Micro-Effusion Delivery Unit for Space Applications (MEDUSA), seed cassettes, germination paper substrates of varying layers, flax seeds, powered pump and video cameras for data recording.

Procedure: A pump was attached to the MEDUSA for water delivery. Water was delivered to the seed cassettes in 50µl increments during a series of seven parabolas. This procedure was conducted on each flight day. Video images were taken during the entire procedure.

Experiment 2: Water Exposed to a Magnetic Field

Subjects: 1-2 subjects per flight day.

Instruments: Modified Magnetic Field Chamber (polycarbonate box with bar magnet), tether and video camera. Both items were mounted on a polycarbonate base.

Procedure: The chamber was filled with water on the ground. The chamber and the video camera were tethered and allowed to free float. This procedure was conducted on each flight day. Video images were taken during the entire procedure.

Experiment 3: Simulated Fixation Flow

Subjects: 2 subjects per flight day.

Instruments: Standard Magnetic Field Chamber (MFC), a storage tower, a modified Lexan MFC, a powered pump, a waste bag, water and video cameras.

Procedure: The MFC and the modified MFC were filled with water using a powered pump. No fixative was used. Water flow through both MFCs was video recorded.

Experiment 4: Kennedy Space Center Fixation Tube

Subjects: 1 subject per flight day.

Instruments: Kennedy Space Center Fixation Tube (KFT) with plant sample, video camera.

Procedure: The KFT was loaded on the ground with a plant sample and water (to simulate fixative). No fixative was used. The flow of water through the o-rings and onto the plant was recorded. In addition, the ability of the water to cover the plant in microgravity was noted.

Experiment 5: Petri Dish Fixation Unit

Subjects: 1 subject on flight days 2 and 3.

Instruments: Petri Dish Fixation Unit (PDFU) with moss sample, actuator rod and video camera.

Procedure: The PDFU was loaded on the ground with a moss sample and water (to simulate fixative). No fixative was used. The water was video recorded as it entered the petri dish to observe if 3 ml of water would be sufficient to cover the sample.

RESULTS:

- Experiment 1 - The experiment performed very well, with nearly all data points gathered.
- Experiment 2 - Rather than the water forming a ball in the chamber during microgravity, the air formed a ball within the water. This was an unexpected finding. The magnet did not appear to displace water to the extent observed in previous research.
- Experiment 3 - Both MFCs functioned very well, and the water flow through the MFCs was as predicted.
- Experiment 4 - The plant was submerged in water as expected, indicating that the design will provide adequate fixation.

- Experiment 5 - A total of three PDFUs were fired. Two of the PDFUs did not have any visible water in the petri dish following firing. A water droplet was observed in the third petri dish.

DISCUSSION:

- Experiment 1- The observation of water moving through the different layers of paper was extremely valuable.
- Experiment 2 -The air bubble forming within the water could have been an effect caused by the air being displaced by the magnet.
- Experiment 3 - The design of the fixation system in the spaceflight hardware requires the fixative to flow through a series of chambers in the MFC. This fixation system was simulated using water and performed as expected.
- Experiment 4 - The original concern with this piece of hardware was that the fixative would form a bubble around the plant and not cover the plant. This effect was not observed in these experiments.
- Experiment 5 - It appears that 3 ml of water will not be sufficient to cover the entire sample.

CONCLUSION:

- Exeriment 1 - The two layers of normal, one layer of heavy, and the one layer of normal with one layer of heavy germination papers will mostly likely be used for flight.
- Experiment 2 -The current design of the hardware will meet the investigator's fixation requirements.
- Experiment 3 - The current design of the hardware will meet the investigator's requirements.
- Experiment 4 - The current design of the hardware will meet the fixation requirements.
- Experiment 5 - The current volume of water might have to be increased from 3 ml to allow for adequate coverage.

PHOTOGRAPHS:

99EO6203 to 99EO6208
99EO6210
99EO6212
99EO6231 to 99EO6241
99EO6247 to 99EO6248
99EO6250 to 99EO6255
99EO6263 to 99EO6266
99EO6620
99EO6636 to 99EO6640

VIDEO:

KC-135 flights week of June 7-11, 1999, PMU: 11/49332

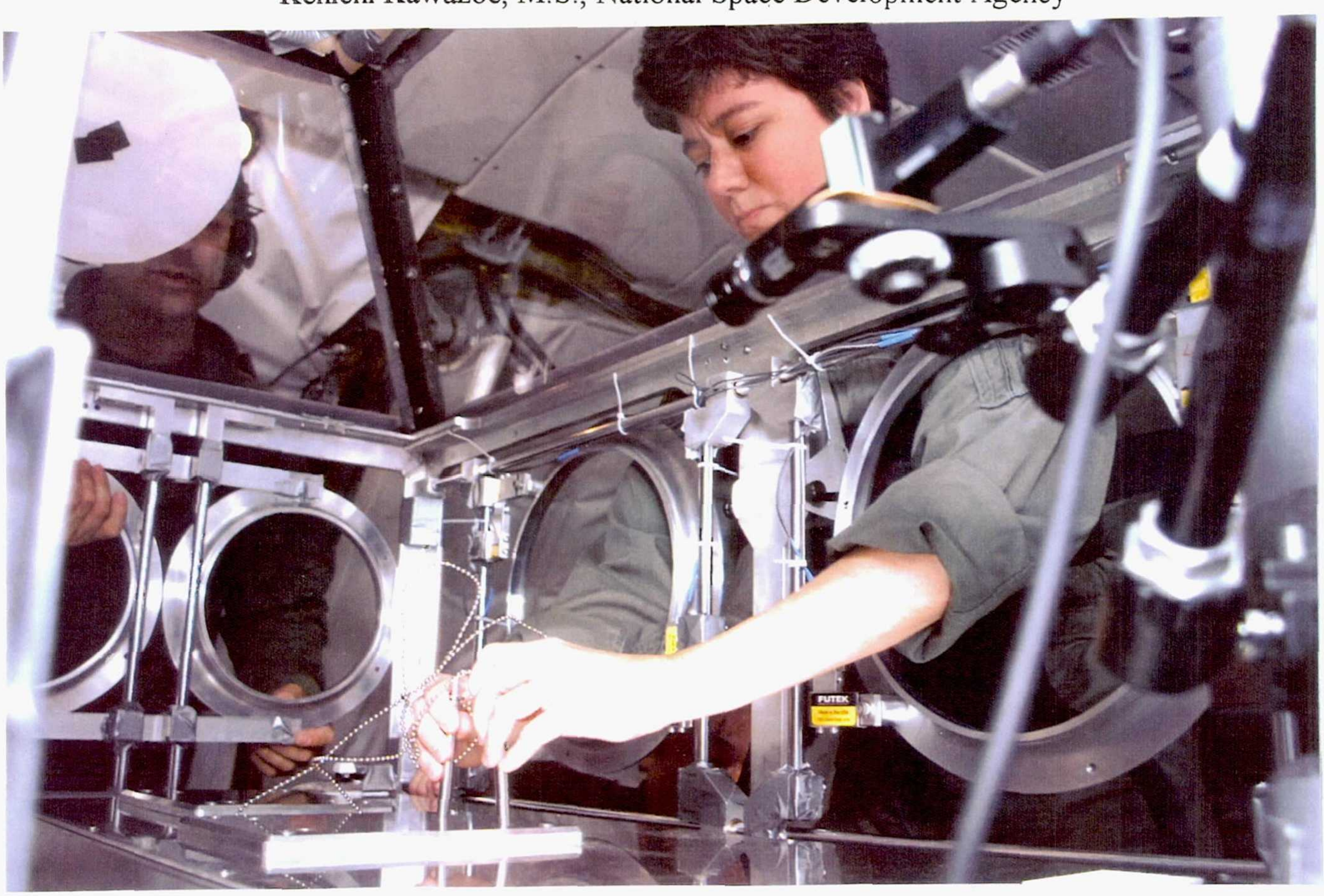
Videos available from Imagery and Publications Office (GS4), NASA/JSC.

TITLE:
Ergonomic Evaluation of the Life Sciences Glovebox (LSG)

FLIGHT DATES:
June 8-10, 1999

PRINCIPAL INVESTIGATORS:
Gita Murthy, Ph.D., University of California
David Rempel, M.D., University of California

CO-INVESTIGATORS:
Richard Brewer, M.S., University of California
Ron Tal, B.S., University of California
Hiroshi Fujino, M.S., Ishikawajima-Harima Heavy Industries Co. Ltd
Fumitaka Sugimura, M.S., Ishikawajima-Harima Heavy Industries Co. Ltd
Toshiaki Ueno, M.D., Ph.D., National Space Development Agency
Kenichi Kawazoe, M.S., National Space Development Agency



NASA Photo: 99EO6228

GOAL:

The goals of Phase II of the LSG ergonomic study were to:

1. Evaluate the optimal LSG design derived from Phase I while evaluators perform hand intensive task from the primary and the secondary gloveport locations,
2. Evaluate the effectiveness of a torso restraint in conjunction with a leg restraint while evaluators perform a hand intensive task, and
3. Confirm reach zones to the back wall of the LSG for operations with height range from the large Caucasian male to the small female.

INTRODUCTION:

The Univesity of California was contracted by Ishikawajima-Harima Heavy Industries, Inc. (IHI) in collaboration with NASDA, to perform an ergonomics evaluation of the Life Sciences Glovebox (LSG) design to accommodate the 95%ile Caucasian male and the 5%ile Japanese female crew members. In Phase I of this investigation, we evaluated the LSG design from an ergonomics and human factor's perspective using retired and current astronauts with prior glovebox experience as subjects (Phase I). In Phase I, we used posture analysis, detailed astronaut interviews, reach and dissection tasks to evaluate lower body and torso restraint systems, gloveport size and location, window tilt angles, LSG work volume depth, and air location. Final Phase I recommendations for the LSG design also considered LSG requirements posed by NASA Ames Research Center.

METHODS AND MATERIALS:

The ergonomic evaluation test protocol executed on board the KC-135 was approved by NASA, Johnson Space Center, and was carried out on June 8-10, 1999. Two experienced flyers were designated as the evaluators on each of 3 flight days. A total of 6 flyers (2 per day) participated as evaluators in this experiment. On flight days two and three, the evaluators were astronauts (2 females, 2 males). Two of the four astronauts who participated in this flight experiment also participated in Phase I of the study. An additional 2 to 3 flyers per flight carried out the experiment by setting up restraints, guiding the evaluators through their tasks, and spotting the evaluators.

The LSG was mounted and secured to the floor of the KC aircraft. The prototype torso restraint system involved a Velcro-coated metal plate mounted just below the bend point, centered between the primary gloveports. The plate retracted into the LSG when a condition of the protocol did not call for a torso restraint. In addition, leg restraints, Foot Restraint Equipment Device (FRED) and Long Duration Crew Restraint (LDCR), were mounted and secured to the floor of the aircraft at the primary and secondary gloveport locations, respectively. Both restraint systems were adjusted to accommodate each evaluator. FRED and LDCR restraint systems allowed for distance adjustaibility between knee and foot pads, and knee flexion angle. In addition, FRED allowed for overall height adjustability, which LDCR did not. When performing tasks from either the primary or secondary gloveport locations, evaluators always used either FRED or LDCR.

Each of the primary gloveports was instrumented with 4 load cells to measure force exerted by the evaluators while performing hand tasks (peg insertions). Eight amplifiers provided excitation voltage to the load cells. A 16 channel, 12 bit DAQ PCMCIA card was incorporated into a PC LapTop computer which was mounted and secured to the LSG to collect and store data for post experiment data analysis (LabView 5.0). The purpose of the force measurement was to determine the site on the gloveport rings which received the most contact force.

The protocol was structured to test a specific task during each parabola of the flight. A total of 40 parabolas (20 parabolas/evaluator) per flight were carried out (3 flights total). The first two parabolas were always practice parabolas during which evaluators ingressed and egressed from FRED or LDCR. The evaluator then performed peg insertions and reach tasks from the primary gloveport location with and without the torso restraint during 12 parabolas. The evaluator then switched position to the secondary gloveport location and performed peg insertions and reach tasks during the last 8 parabolas. There was no evaluation of a torso restraint at the secondary gloveport location. The second evaluator performed the same tasks, but the order of testing with and without torso restraint between evaluators was randomized.

The hand intensive task included repeated insertion of 2 pegs into 4 holes using left and right hands simultaneously. The evaluators were instructed to insert and remove the pegs as rapidly as possible as soon as they were comfortably situated in the restraints. The reach task from the primary port required the evaluator to hold a marker at the tip and write a character on the back wall. The reach task from the secondary gloveport location required the evaluator to reach along the back wall to touch the Velcro patch attached to the back wall. The extreme reach point with the right and left hand was marked. Evaluator postures and task performance were documented by 3 video cameras. A lipstick camera was mounted within the left side of the LSG to capture the peg insertion tasks, and the internal view of the primary and secondary gloveports. The video footage from this camera was used to calculate rate of peg insertions per parabola, and to confirm whether or not evaluators used a torso restraint. A second camera captured the right side view of the evaluator at the primary gloveport location. The third camera mounted behind and to the right of the primary gloveport location captured the left side view of the evaluator at the secondary gloveport location. In addition, there was audio and video downlink and an audio uplink to keep the ground investigators informed of events in real time during each flight.

At the end of each flight, a questionnaire was administered individually to each evaluator, and subjective comments regarding specific aspects of the LSG design and the torso restraint were collected.

RESULTS:

In general, the primary and secondary gloveport locations were favorably accepted.

Four out of six evaluators were advocates of the torso restraint, and thought that it helped stabilize the head and the hands during hand intensive tasks.

The window tilt angle from the primary and secondary gloveport location were desirable as currently designed.

The rate at which evaluators (n=6) inserted pegs into holes from the primary gloveport location with a torso restraint was 0.75±0.17 pegs/sec (mean±SD), and without the torso restraint was 0.81±0.12 pegs/sec. From the secondary gloveport location, the rate for peg insertion without the torso restraint was 0.83±0.11 pegs/sec. There was no significant difference between any of the conditions (p=0.10).

Detectable forces were applied against the primary gloveport.

DISCUSSION:

Based on the evaluators comments and observations, the gloveport locations for both the primary and secondary positions ought to remain the same as the current design. Although the likely long-term benefits of the torso restraint could not be adequately tested during either Phase I or II of this study, the need for a simple torso restraint may be important. The window tilt angles also ought to remain unchanged.

Please note that due to the confidential nature of our recommendations and this project, not many detailed results or discussion/recommendations are disclosed in this report.

PHOTOGRAPHS:

99EO6221
99EO6225 to 99EO6230
99EO6268 to 99EO6274
99EO6629 to 99EO6631
99EO6633 to 99EO6635
99EO6641 to 9966EO43

VIDEO:

KC-135 flights week of June 7-11, 1999, PMU: 11/49332

Videos available from Imagery and Publications Office (GS4), NASA/JSC.

20000025663

TITLE:
Medical Operations KC-135 Familiarization Flight

FLIGHT DATES:
June 11, 1999

532/52

434592

PRINCIPAL INVESTIGATORS

Chris Dawson, Wyle Life Sciences

CO-INVESTIGATORS:

Paul Stoner, NASA/Johnson Space Center
Brian Arenare, University of Texas Medical Branch
Angie Strickland, Wyle Life Sciences
Fredrick Rudge, Patrick Air Force Base
Greg Lowdermilk, Patrick Air Force Base

NASA Photo: 99EO6678

GOAL:

To familiarize new Medical Operations Branch personnel with the effects of weightlessness on medical equipment and procedures, as well as with the process required to conduct a KC-135 flight.

OBJECTIVES:

Preflight

1. Prepare a KC-135 flight test plan.

2. Prepare flight hardware.

3. Conduct preflight briefing and ground-based practice session.

4. Attend Test Readiness Review.

5. Attend medical briefing.

6. Conduct final inventory of all hardware and supplies and transport equipment to Ellington Field for scheduled reporting time.

7. Properly load and secure hardware onto aircraft.

In-Flight

8. Experience and evaluate the effects of microgravity on intravenous (IV) insertion procedure, drug administration, and on medical fluids (MEDICAL FLUIDS STATION).

9. Experience and evaluate the effects of microgravity on cardiopulmonary resuscitation (CPR), patient restraint, and rescuer restraint (RESTRAINT STATION).

10. Experience and evaluate the effects of microgravity on establishing a patent airway (AIRWAY STATION).

Postflight

11. Unload equipment from aircraft.

12. Prepare a KC-135 final report.

INTRODUCTION:

As new personnel join the Medical Operations Branch, it is critical that they understand the effects of microgravity on medical procedures, hardware, and supplies. The familiarization flight provided new personnel with a better understanding of the effects of microgravity on (1) medical procedures, (2) patient and rescuer restraint, (3) medical fluids, and (4) medical training for space flight. The flight process also provided experience in flight proposal preparation, flight test plan preparation and execution, and final report preparation. In addition, first time flyers gained insight on their performance level in microgravity for future flights.

METHODS AND MATERIALS:

An initial training session was held to familiarize the new flyers with all aspects of flying on the KC-135 (see Appendix). The documentation required for requesting and reporting a KC-135 flight was covered in detail. New flyers were given templates for writing their own reports, and were given assignments to write a test plan and final report. The entire preflight, in-flight, and postflight process was reviewed, and videos of previous familiarization flights were shown.

A skills session on the medical procedures that would be attempted in-flight was held, following the initial briefing. Flyers were introduced to the procedures required at each station and were given additional time to build confidence in their skills and operations for the flight.

Flyers had the option of attending the Test Readiness Review (TRR) for flight week. Flyers were introduced to the procedures involved in TRR and observed all experiment presentations that were given.

Co-investigators were required to load and secure all flight hardware before the flight, and to unload all flight hardware after the flight. A debrief was held following the flight to discuss benefits of the flight and associated requirements and procedures.

During the flight, the co-investigators were stationed as outlined in Table 1.

Parabola	Medical Fluids	Restraint	Airway
3-10	Arenare	Stoner/Rudge/Lowdermilk	Strickland
11-20	Strickland	Stoner/Rudge/Lowdermilk	Arenare
21-30	Rudge/Stoner	Strickland/Arenare	Lowdermilk
31-40	Lowdermilk	Strickland\Arenare	Rudge/Stoner

Table 1: KC-135 Familiarization flight procedure assignments.

At the Medical Fluids Station, co-investigators attempted to start an intravenous saline fluid infusion. The station consisted of the following:

1. IV trainer arm
2. IV supplies
3. Table (2' X 4')

The IV trainer arm and IV supplies were mounted to the table with Velcro and bungee cords.

At the Restraint Station, co-investigators attempted to deploy the Crew Medical Restraint System (CMRS), restrain a training manikin, and perform CPR procedures. The station consisted of the following:

1. Transport Manikin (Full Body)
2. Crew Medical Restraint System

The KC test fixture was bolted to the floor and used as an attachment point for the CMRS. The manikin was restrained with bungee cords.
At the Airway Station, co-investigators attempted to maintain a patent airway by inserting a nasopharyngeal airway, an oral airway, and by intubating. The station consisted of the following:

1. Intubation Manikin (Head)
2. Intubation supplies

The Intubation manikin was strapped to the floor of the aircraft, and the supplies were mounted next to the manikin with tape.

RESULTS:

Three co-investigators attended the preflight training session, the skills session, the medical briefing, one attended the TRR, and all co-investigators attended the postflight debrief. Three co-investigators submitted a test plan and final report to the principal investigators who reviewed the reports and returned them with comments and corrections. Co-investigators also performed hands-on loading and unloading of the flight hardware onto and off of the aircraft.

Three co-investigators were able to perform all of the assigned procedures at every station. The other two became incapacitated due to illness and could not continure

DISCUSSION:

All objectives related to the process of requesting and preparing a KC-135 flight were met by participating co-investigators. Each learned what to include in preflight and postflight documentation. Test plans and final reports were submitted to the principal investigators for review and were then sent back to the co-investigators for revision, if required. This process simulated what the co-investigators would experience if conducting their own KC-135 flight as principal investigators.

Although some procedures at each of the three stations were not fully completed, co-investigators were able to experience the effects of microgravity on common medical procedures. All co-investigators experienced their own reaction to reduced gravity flight, preparing them for future flights.

CONCLUSIONS:

Overall, the objectives of the KC-135 Familiarization Flight were met. All co-investigators agreed that the KC-135 Familiarization Flight and associated training provided them with an excellent knowledge level from which to conduct their own flights. An added benefit was the first hand experience of microgravity, which was felt to be beneficial for personnel involved in the design or training of medical equipment and procedures. It was also beneficial for mission controllers who gained a new perspective on the actual use of medical hardware in weightlessness.

APPENDIX:

I. Objectives of Familiarization Flight

II. Requirements of Familiarization Flight
   1. Test Plan - due June 4
   2. Test Readiness Review – June 7, 10:00 a.m.
   3. Load/unload plane, in-flight activities - week of June 7
   4. Final Report - due June 18

III. KC-135 Documentation
   1. Proposal (example included)
   2. Test Plan (example included) - assignment
   3. Final Report (example included) - assignment

IV. Pre-Flight
   1. Equipment preparation
   2. TRR
   3. Loading plane

V. In-Flight
   1. Microgravity Procedures
   2. 2-g Procedures
   3. Timeline

VI. Post-Flight
   1. Unloading plane
   2. Debrief

VII. Helpful Hints
   1. Medication
   2. Safety
   3. What to wear/bring
   4. Sickness procedures

VIII. Training Session (HMF Lab)
   1. Airway
   2. Medical Fluids
   3. Restraint

REFERENCES:

JSC Reduced Gravity Program User's Guide	JSC-22803
Manifesting Procedures for KC-135	JSC-22803 (supplement)
KC-135A Pre-Flight Safety Briefing	JSC-23695

PHOTOGRAPHS:

99EO6702 to 99EO6657

VIDEO:

KC-135 flights week of June 7-11, 1999, PMU: 11/49332

Videos available from Imagery and Publications Office (GS4), NASA/JSC.

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Appendix

Background Information about the KC-135 and the Reduced-Gravity Program

The Reduced-Gravity Program, operated by the NASA/Johnson Space Center (JSC), provides engineers, scientists, and astronauts alike, a unique opportunity to perform testing and training in a weightless environment but without ever having to leave the confines of the earth's orbit. Given the frequency of Space Shuttle missions and the anticipated construction and eventual habitation of the New International Space Station, the Reduced-Gravity Program provides a truly ideal environment to test and evaluate space hardware and experimental procedures prior to launch.

The Reduced-Gravity Program was established in 1959 to investigate the reactions of humans and hardware during operations in a weightless environment. A specially modified KC-135 turbojet (KC-135A), flying parabolic arcs, produces periodic episodes of weightlessness lasting 20-25 secs. The KC-135 is sometimes also flown to provide short periods of lunar (1/6) and Martian (1/3) gravity. Over the last 35 years, approximately 100,000 parabolas have been flown in support of the Mercury, Gemini, Apollo, Skylab, Space Shuttle, and Space Station programs.

Excluding the KC-135 Flight Crew and the Reduced Gravity Program Test Directors, the KC-135 accommodates seating for a maximum of 21 other passengers. The KC-135's cargo bay provides a test area that is approximately 60 feet long, 10 feet wide, and 7 feet high. The aircraft is equipped with electrical power, overboard venting system, and photographic lights. When requested and available, professional photography and video support can be scheduled to document activities inflight.

A typical flight lasts 2 to 3 hours and consists of 30 to 40 parabolas. The parabolas are flown in succession or with short breaks between maneuvers to allow time for reconfiguring test equipment.

For additional information concerning flight weeks sponsored by the Johnson Space Center's Life Sciences Research Laboratories or other Reduced-Gravity Program opportunities, please contact:

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Explore the Zero Gravity Experiments and Aircraft Operations Web pages at:
http://zerog.jsc.nasa.gov/
http://jsc-aircraft-ops.jsc.nasa.gov/