PREDICTION OF SUSCEPTIBILITY TO SPACE MOTION SICKNESS*

Investigators: J. L. Homick, Ph.D., M. F. Reschke, Ph.D., and J. M. Vanderploeg, M.D.

INTRODUCTION

Space motion sickness (SMS) is experienced by about 50% of crewmembers during the first several days of exposure to the microgravity space flight environment (1,2,3). Predominant symptoms of the syndrome are headache, depressed appetite, general malaise, lethargy, gastrointestinal discomfort, nausea, and vomiting. As in other forms of motion sickness, the syndrome may reduce self-motivation and result in decreased ability to perform demanding tasks. The syndrome is self-limiting. Complete recovery from major symptomatology, in other words adaptation to the space flight environment, occurs within two to four days. After complete adaptation occurs, crewmembers appear to be immune to the development of further symptomatology.

The overall incidence to date of SMS in the U.S. and Soviet manned space programs is summarized in Figure 1. Available data indicates that the frequency of occurrence of this syndrome has been approximately equal in both countries. An important feature of these data is that with the advent of larger spacecraft in the

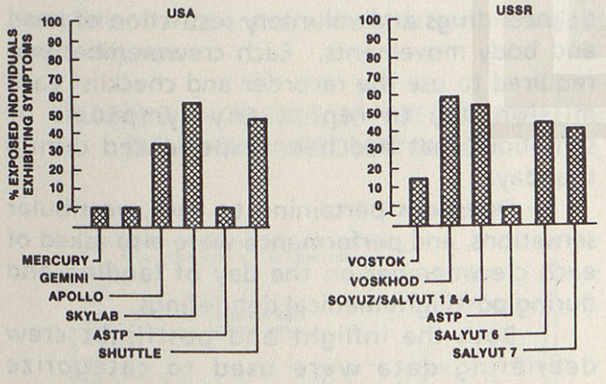

Figure 1. SMS experience.

U.S. program (i.e., Apollo, Skylab and Shuttle) that permit greater mobility of crewmembers, the incidence of SMS has increased.

In an effort to resolve the SMS or at least minimize the operational impact of the syndrome, NASA has significantly expanded its research efforts in this area. As part of this expanded effort, a systematic program of operationally oriented motion sickness data collection was implemented on most individuals assigned to Shuttle flights from April 1981 to April 1985. The primary objective of this program was to collect preflight, inflight and postflight data on the crewmembers in an effort to begin validating ground based tests which may be predictive of susceptibility to the syndrome. The development of reliable predictors is operationally important because they would permit the a priori identification of individual crewmembers for whom special preventative measures should be taken. A secondary objective of the program was to acquire data which could be used to validate countermeasures for the syndrome.

PROCEDURES

Preflight data collection involved several different procedures. Approximately three to six months prior to flight, each crewmember completed a questionnaire designed to elicit information regarding past experiences with various types of motion environments and responses to those environments.

Also during the three to six months before flight each crewmember was tested at least one time for susceptibility to experimentally induced motion sickness. Three different laboratory test procedures were used to provide a ground-based data point against which inflight susceptibility could be compared.

For the first nine Shuttle missions, which involved 29 different crewmembers, a standard Coriolis Sickness Susceptibility Index test (CSSI),

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originally developed by Miller and Graybiel (4) was used. This procedure, which stimulates primarily the semi-circular canals, requires the performance of head movements while rotating at a constant velocity in a servo-controlled chair. Prior to the start of the test the crewmember was instructed on how to report his or her symptoms of motion sickness to an observer who was skilled in the recognition of signs and symptoms of motion sickness. The signs and symptoms were recorded and scored according to the diagnostic categorization shown in Table 1 (4). The test was terminated when the blindfolded crewmember reached the Malaise III level of motion sickness or performed 150 head movements, whichever occurred first. The higher the score, the longer the subject continued the test, indicating a greater resistance to motion sickness. A majority of the crewmembers on the first nine Shuttle missions were tested at least one additional time with the CSSI procedure in order to evaluate the efficacy of an anti-motion sickness medication. The medication most frequently evaluated was oral scopolamine (.4 mg) plus dexedrine (5 mg).

TABLE 1. DIAGNOSTIC CATEGORIZATION OF ACUTE MOTION SICKNESS LEVELS

CATEGORY	PATHOGNOMONIC 16 POINTS	MAJOR 8 POINTS	MINOR 4 POINTS	MINIMAL 2 POINTS	AQS* 1 POINT
NAUSEA SYNDROME	NAUSEA III,[†] RETCHING OR VOMITING	NAUSEA II	NAUSEA I	EPIGASTRIC DISCOMFORT	EPIGASTRIC AWARENESS
SKIN		PALLOR III	PALLOR II	PALLOR I	FLUSHING/ SUBJECTIVE WARMTH ≥ II
COLD SWEATING		III	II	I	
INCREASED SALIVATION		III	II	I	
DROWSINESS		III	II	I	
PAIN					
CENTRAL NERVOUS SYSTEM					HEADACHE (PERSISTENT) ≥ II DIZZINESS (PERSISTENT) - EYES CLOSED ≥ II EYES OPEN - III

LEVELS OF SEVERITY IDENTIFIED BY TOTAL POINTS SCORED

FRANK SICKNESS (FS)	SEVERE MALAISE (M III)	MODERATE MALAISE A (M IIA)	MODERATE MALAISE B (M IIB)	SLIGHT MALAISE (M I)
- 16 POINTS	8 - 15 POINTS	5 - 7 POINTS	3 - 4 POINTS	1 - 2 POINTS

*AQS - ADDITIONAL QUALIFYING SYMPTOMS

[†]III - SEVERE OR MARKED, II - MODERATE, I - SLIGHT

The second motion sickness susceptibility procedure used was a modified version of an off-vertical rotation or OVR test originally developed by Graybiel and Miller (5). The OVR produces a rotating linear acceleration and is essentially an otolith stimulus. During this procedure crewmembers were blindfolded and restrained in the rotating chair with lap, shoulder and leg straps. The head was also restrained. While in the vertical position the chair was accelerated to a velocity of 20 rpm and rotated for 5 minutes. Following stabilization of 0° tilt the angle of tilt of the chair was increased in 5° increments at 5 minute intervals until the crewmember reached the Malaise III level of symptoms or the chair had been maintained at 30° tilt for 5 minutes. The OVR test was performed on 29 individual astronauts most of whom flew subsequent to the ninth Shuttle flight.

The third procedure used was a modified version of an eyes open sudden-stop test developed by Graybiel and Lackner (6). This test assessed susceptibility to a vestibulo-visual interaction stimulus. Visual stimulation was provided by a stationary optokinetic field which surrounded the chair in which the crewmember was restrained. The chair was accelerated to a velocity of 50 rpm and held at that velocity for 30 seconds. The chair was then decelerated at 150°/sec to a complete stop and maintained at zero velocity for 30 seconds, after which the sequence was repeated for a total of 20 clockwise and 20 counterclockwise stops or until the Malaise III level of symptoms was reached, whichever occurred first. Data were collected on only six crewmembers with this procedure.

Inflight data collection was limited to the use of a microcassette tape recorder and a motion sickness symptom checklist. The checklist was similar in content to the diagnostic scale shown in Table 1 and allowed comparisons between the pattern of symptoms that occurred during the preflight pro vocative tests and those that occurred inflight. The checklist also required crewmembers to report on preventative measures used such as anti-motion sickness drugs and voluntary restriction of head and body movements. Each crewmember was required to use the recorder and checklist each mission day to report any symptoms or sensations that had been experienced during that day.

Questions pertaining to SMS, vestibular sensations, and performance were also asked of each crewmember on the day of landing and during postflight medical debriefings.

Both the inflight and postflight crew debriefing data were used to categorize crewmembers as susceptible or non-susceptible to SMS. Those who were defined as being susceptible were further classified into mild, moderate and severe subgroups for subsequent data analysis. Operational definitions for SMS categorization are given in Table 2.

TABLE 2. SMS CATEGORIZATION

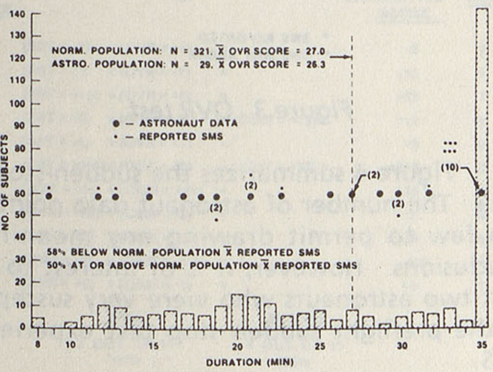
NONE (0):	NO SIGNS OR SYMPTOMS REPORTED WITH EXCEPTION OF MILD TRANSIENT HEADACHE OR MILD DECREASED APPETITE
MILD (1):	ONE TO SEVERAL SYMPTOMS OF A MILD NATURE; MAY BE TRANSIENT AND ONLY BROUGHT ON AS THE RESULT OF HEAD MOVEMENTS; NO OPERATIONAL IMPACT; MAY INCLUDE SINGLE EPISODE OF RETCHING OR VOMITING; ALL SYMPTOMS RESOLVED IN 36-48 HOURS
MODERATE (2):	SEVERAL SYMPTOMS OF A RELATIVELY PERSISTENT NATURE WHICH MAY WAX AND WANE; LOSS OF APPETITE; GENERAL MALAISE, LETHARGY AND EPIGASTRIC DISCOMFORT MAY BE MOST DOMINANT SYMPTOMS; INCLUDES NO MORE THAN TWO EPISODES OF VOMITING; MINIMAL OPERATIONAL IMPACT, ALL SYMPTOMS RESOLVED IN 72 HOURS
SEVERE (3):	SEVERAL SYMPTOMS OF A RELATIVELY PERSISTENT NATURE THAT MAY WAX AND WANE; IN ADDITION TO LOSS OF APPETITE AND STOMACH DISCOMFORT MALAISE AND/OR LETHARGY ARE PRONOUNCED; STRONG DESIRE NOT TO MOVE HEAD; INCLUDES MORE THAN TWO EPISODES OF VOMITING; SIGNIFICANT PERFORMANCE DECREMENT MAY BE APPARENT; SYMPTOMS MAY PERSIST BEYOND 72 HOURS

RESULTS

Results include preflight and inflight symptomatology data, antimotion sickness drug data and preflight versus inflight motion sickness susceptibility data.

As indicated in Table 3 there is a striking difference in the pattern of symptomatology generated inflight versus during the ground-based tests. Subjective warmth, sweating, and pallor, which were dominant ground-based test symptoms, were almost nonexistent inflight. In contrast, vomiting, anorexia, headache, malaise and lethargy were dominant inflight symptoms. The vomiting episodes often occurred abruptly with little or no prodromal nausea, although a sensation of stomach fullness or discomfort was often present prior to vomiting. In most cases, vomiting resulted in relief from the uncomfortable stomach sensations, although for some crewmembers the discomfort would gradually return.

TABLE 3. INCIDENCE OF PREFLIGHT VS. INFLIGHT SYMPTOMATOLOGY



The specific nature and time course of inflight symptomatology tends to be highly variable. Some crewmembers reported that symptoms appeared within the first one to two hours of the mission. Others did not become aware of symptoms until the second day of flight. In general, however, symptoms began during the first day of flight, plateaued between 24-48 hours and gradually diminished between approximately 48-96 hours. During this time the symptoms usually waxed and waned in severity. Unquestionably, head and body movements exacerbated the symptomatology. Accelerometric data obtained by Oman during the Spacelab 1 mission (STS-9), and subsequently confirmed by verbal reports from a number of crewmembers, indicate that in microgravity head movements in the pitch and roll planes are the most provocative (7,8).

Anti-motion sickness and/or anti-emetic medication was used by 40 of the 65 crewmembers included in this study. As indicated in Table 4 the oral scopolamine plus dexedrine combination was the most frequently used with 25 crewmembers taking one or more doses during the first few days of flight. Oral metoclopramide was used by 18 crewmembers in an effort to restore gastric motility and alleviate nausea and vomiting. Of the 31 crewmembers who experienced symptoms, 29 used medication during the course of their symptomatology.

TABLE 4. SHUTTLE ANTI-MOTION-SICKNESS DRUG USE SUMMARY

DRUG NAME	NUMBER OF CREWMEMBERS
SCOPOLAMINE (.4 MG) + DEXEDRINE (5 MG) - ORAL	25
SCOPOLAMINE (.4 MG) - ORAL	1
PHENERGAN (25 MG) - SUPPOSITORY	3
PHENERGAN (25 MG) + EPHEDRINE (25 MG) - ORAL	1
METACHLOPRAMIDE (10 MG) - ORAL	18
COMPAZINE (10 MG) - SUPPOSITORY	1
TRANSDERM SCOP	1

Results related to a comparison of preflight motion sickness data with SMS are by no means unequivocal.

The motion experience questionnaire indicated that all of the crewmembers had a minimal history of susceptibility to terrestrial forms of motion sickness. The questionnaire revealed that a few had experienced some motion sickness during past exposures to aerobatic flight, parabolic flight, and heavy sea conditions. The questionnaire results, however, did not correlate with the actual incidence of SMS reported.

Table 5 provides an overall summary of group mean differences between the SMS susceptible and non-SMS susceptible subgroups for each of the preflight motion sickness susceptibility tests used. The subgroups of astronauts who experienced SMS were slightly more susceptible to the preflight motion sickness tests than were the non-SMS susceptible astronauts. However, the test score ranges for all subgroups are large and the difference between the means of the subgroups for each test are not statistically significant. In a further attempt to establish a relationship between the ground-based tests and SMS, correlation coefficients between the ground-based test scores and the scores assigned for the inflight level of severity of SMS symptoms were computed. The correlation coefficients were non-significant for all three ground-based tests.

TABLE 5. PREFLIGHT MOTION SICKNESS TEST RESULTS VS. SMS

SYMPTOM	*INFLIGHT NUMBER	*INFLIGHT PERCENT	PREFLIGHT
VOMITING	26	40	0
ANOREXIA	23	35	0
HEADACHE	20	31	0
MALAISE	18	28	0
STOMACH AWARENESS	17	26	18
LETHARGY	15	23	0
NAUSEA	13	20	55
DROWSINESS	6	9	3
DISEQUILIBRIUM/DIZZINESS	6	9	3
SALIVATION	0	0	18
PALLOR	?	?	85
SWEATING	0	0	75
SUBJECTIVE BODY WARMTH	0	0	48

*BASED ON 65 INDIVIDUALS, 31 OF WHOM REPORTED SMS

As an alternative approach to determining whether or not the preflight susceptibility tests might have some predictive value for SMS, the astronaut data for each test was compared to a frequency distribution of non-astronaut normative data. The normative data were collected over the past several years by the Johnson Space Center Neurophysiology Laboratory. Figure 2 summarizes the CSSI test data. The hatched bars are the normative data and the closed circles are the astronaut data. The "star" symbol indicates astronauts who reported SMS. The astronaut mean CSSI score is 28.7 while the normative population mean CSSI score is 14.0. Of potentially greater significance is the finding that 67% of the astronauts whose CSSI score was below the population mean experienced SMS, while only 40% whose scores were above the population mean experienced SMS.

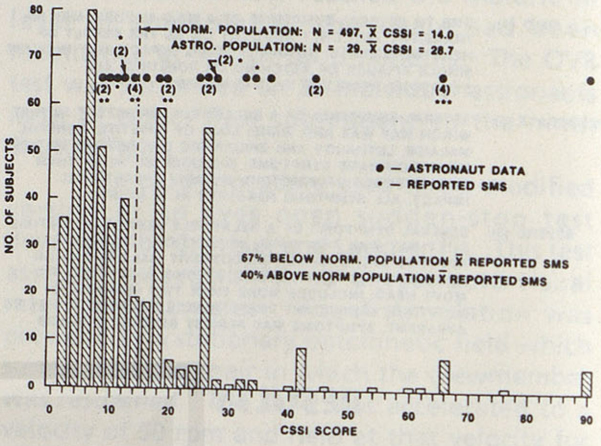


Figure 2. CSSI test.

Data from the OVR test are shown in a similar fashion in Figure 3. Here there is virtually no difference between the astronaut and normative population data. The mean OVR test scores are almost identical and there were as many crewmembers above the normative population mean who reported SMS as there were below the mean.

IN FLIGHT	CSSI *SMS	CSSI NO SMS	OVR SMS	OVR NO SMS	SST (EO) SMS	SST (EO) NO SMS
N	14	15	15	14	3	3
%	48	52	52	48	50	50
PREFLIGHT						
$\bar{X}$ =	27.4	30.9	25.7	27.1	10.0	19.7
RANGE	8.4-64.5	11.2-90.0	17.0-35.0	9.0-35.0	2.0-26.0	6.0-40.0
**F =	.192		.201		.545	
P =	.69		.66		.51	

* SMS REPORTED
** ONE WAY ANOVA

Figure 3. OVR test.

Figure 4 summarizes the sudden-stop test data. The number of astronaut data points are too few to permit drawing any meaningful conclusions. However, it is of interest to note that two astronauts who were very susceptible to the preflight sudden stop test experienced SMS.

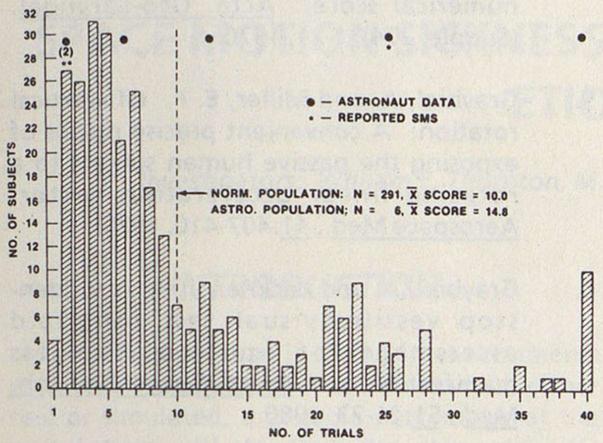


Figure 4. Sudden-stop test.

All of the data summarized thus far in this report have compared SMS susceptibility to a single preflight test. Table 6 compares a weighted ground-based test score with SMS susceptibility for each of 11 crewmembers on whom data were collected on two or more of the preflight tests. The weighted score is the algebraic sum of the differences between the astronaut's test scores and the normative population means for each test. It would be predicted that a positive weighted score (i.e., greater than average resistance to experimentally induced motion sickness) should relate to a lack of SMS and a negative weighted score should be related to the presence of SMS. A correct match was obtained in 64% of the cases.

TABLE 6. WEIGHTED GROUND-BASED TEST SCORES VS. SMS

WEIGHTED SCORE = Σ(CREW Δ'S FROM NORM POPULATION $\overline{X}$)

HYPOTHESIS:

- POSITIVE WEIGHTED SCORE SHOULD BE RELATED TO LACK OF SMS
- NEGATIVE WEIGHTED SCORE SHOULD BE RELATED TO PRESENCE OF SMS

CREW MEMBER					WEIGHTED SCORE	SMS
1	(SST = -8)	+ (OVR = +3)	=		-5	1
2	(SST = -8)	+ (OVR = -7)	=		-15	1
3	(SST = +16)	+ (OVR = +5)	=		+21	1
4	(SST = +3)	+ (OVR = -1)	+ (CSSI = +19)	=	+21	1
5	(SST = -4)	+ (OVR = +7)	=		+3	0
6	(SST = +30)	+ (OVR = +8)	+ (CSSI = +77)	=	+115	0
7	(OVR = +8)	+ (CSSI = +51)	=		+59	0
8	(OVR = -10)	+ (CSSI = -2)	=		-12	0
9	(OVR = +3)	+ (CSSI = -1)	=		+3	0
10	(OVR = -4)	+ (CSSI = -1.5)	=		-4.5	1
11	(OVR = +8)	+ (CSSI = -3)	=		+6	2

HITS	MISSES
7 OUT OF 11	4 OUT OF 11
64%	36%

CONCLUSIONS

On the basis of data collected during this study it can be generally concluded that the prediction of SMS susceptibility on an individual crewmember basis remains a difficult and challenging task. Certainly the use of a single ground-based parameter or test procedure is inadequate. The use of a composite index or weighted score which takes into account several response parameters appears to have greater predictive potential. A larger sample size of composite scores based on the collection of preflight CSSI, OVR and sudden-stop data on Shuttle crewmembers would be desirable. The data needed to derive these composite scores do not exist, nor do plans currently exist to collect these data.

Despite inability to identify preflight, ground-based predictors of SMS susceptibility, there does appear to be one reasonably accurate predictor and that is space flight itself. Out of 16 individuals who have flown two or more space missions only 3 changed their response pattern from one flight to the next. Out of the remaining 13, 7 individuals were symptom free on all of their flights, while the other 6 experienced symptoms on each of their flights. Obviously, the routine use of space flight as the method of identifying SMS susceptible individuals is impractical. Thus the need to identify and validate ground-based methods remains an important issue.

It is important to emphasize that efforts in this area have not been abandoned. The collection of inflight and postflight symptom reporting data is continuing as a standard operating procedure. Improved methods for characterizing the exact nature and time course of SMS are being evaluated. Also, various pre-, in- and postflight measurements of vestibular function are being conducted, the data from which may be useful in our attempts to develop predictors of SMS susceptibility.

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SPACE MOTION SICKNESS: CHARACTERIZATION AND ETIOLOGY

Investigators: William E. Thornton, M.D., Tom Moore, M.D., and Sam Pool, M.D.

INTRODUCTION

Whenever man is placed in environments of motion to which he is unaccustomed, either real or simulated, a sizeable percentage of the population will develop the characteristic syndrome of motion sickness (23). This is a nuisance, or worse to many individuals. It is a significant problem to modern military forces, and much of the study of motion sickness has been sponsored by the military in World War I and II (24). Dr. Graybiel's work in the U.S. Navy is an archetype of such research (6,7,8,9). With the development of a numerical scoring system of signs and symptoms (12) and means with which to rapidly induce motion sickness, research became almost stylized. It was possible to develop such a scoring system only because susceptible individuals develop characteristic signs and symptoms on continued exposure to an environment which produces major sensory conflict.

If such exposure is continued, vomiting and retching may be prolonged, sometimes with prostration (25). After varying amounts of exposure, the majority of subjects develop resistance to the specific stimuli (26). Medication, habituation, and training may be effective in prevention or treatment to varying degrees (27). In addition to the above symptoms, Graybiel proposed a 'sopite' syndrome (10). This may be intertwined with motion sickness and may occur under prolonged mild stimuli, or as a variant of motion sickness under strong stimuli. Features of this syndrome, as proposed, include yawning, drowsiness, disinclination for physical or mental work, and lack of participation in group activities.

Prior to space flight it was predicted that a conflict between the gravity-sensitive statolith organs and unaffected canals would occur in weightlessness and produce a variety of symptoms (20). Early in the Soviet space program, cosmonauts complained of disorientation, illusions, malaise, nausea and vomiting (4). Similar complaints were expressed later by American astronauts in the Apollo Program (15). Based upon these reported symptoms, it was reasonable to consider this motion sickness and treat it accordingly. By the end of Skylab, however, there was reason to doubt that the sickness in space was absolutely identical to that on Earth. There was little correlation between susceptibility on Earth and in space; the medications effective on Earth had questionable efficacy in space, and after a few days of exposure to weightlessness individuals became remarkably resistant to coriolis stimulation, a unique non-specific adaptation (11). After the third Space Shuttle flight, it was obvious that the Shuttle Program also would have to contend with the problem (13,14). There were repeated attempts to document signs and symptoms by means of questionnaires and debriefings, but the first scheduled inflight study (Spacelab 1) was still 18 months away.

An objective inflight investigation of the problem with major emphasis on operational concerns was necessary. This was especially so with accumulating verbal information describing differences between sickness inflight and on Earth. An operationally oriented program by the JSC Astronaut Office and Flight Medicine was mounted on Shuttle flights 4 through 8, and astronaut physicians were added to two of the crews. A large number of investigations were developed and flown as Detailed Supplementary Objectives (DSOs). Some studies of this series have been continued to the present under the aegis of JSC's Space Biomedical Research Institute (SBRI). These investigations used clinical procedures where possible and had the major goals of:

1. Clinical characterization
2. Investigation of etiology
3. Investigation of possible treatment

A listing of studies is given in Table 1. These investigations included personal observations and anecdotal accounts from Astronaut flight experience.

TABLE 1

LISTING OF INFLIGHT SMS STUDIES

Study	Number of Subjects (With SMS)
Head and Eye Motion (EOG) During Launch & Reentry (a)	5 (4)
Head and Eye Motion (EOG) On Orbit(a)	11 (5)
Kinesthetic Repeatability(b)	14 (7)
Eye-hand Tracking Task(b)	12 (7)
Audiometry, pure tone(a)	6 (3)
Physical Examination(a) With Ophthalmoscope	7 (4) 7 (4)
Intraocular pressure(a)	1
Evoked Potentials: audio, short and mid-latency(a)	7 (4)
visual	1 (1)
Fluid Balance(a)	1 (1)
Ambulatory monitoring	
Heart Rate and Blood Pressure(a)	2 (2)
EKG(a)	2 (2)
Heart Rate and Blood Pressure on Reentry(b)	8
Bowel Sound Recording(b)	12 (7)
Leg Plethysmography(b)	10 (5)
Tissue Tonometry(a)	5 (2)
Serum for Causative Agents(b)	3 (3)

(a) Study begun in Astronaut Office and Flight Medicine Inflight Investigation.

(b) Study begun in Astronaut Office and Flight Medicine Inflight Investigation and continued under Space Biomedical Research Institute (SBRI).

CLINICAL CHARACTERIZATION

SYMPTOMS

MOTION SENSITIVITY

These studies observed an amazingly wide and variable range of symptoms in space motion sickness (SMS). Typically, the first indication was hypersensitivity to angular head motion, either alone, or combined with body motion. In many subjects this sensitivity was predominant in the pitch plane, in others it was in yaw; but in most cases it was also present in all other angular axes. This hypersensitivity became noticeable from zero to 1 to 2 hours after exposure. It typically increased to a plateau in several hours and remained at that level until resolution, when it rapidly diminished. It could only be described as a thoroughly unpleasant sensation not to be repeated if possible. One simply wanted a quiet immobile spot during this period of altered sensitivity.

It did not produce visual disturbance or illusion, nor did it obviously produce stomach symptoms as, for example, does out-of-plane head motion in a spinning chair. If anything, it was increased with eyes closed. The sensation strength appeared to be related to the magnitude of the velocity or possibly to the rate of acceleration of movement.

Translation, even reciprocating translation, did not produce these symptoms.

ILLUSIONS, VISUAL DISTURBANCE, ORIENTATION

Illusion of both position and motion was reported as a major symptom in the Russian Program (18) and in some of the Apollo experiences (3). Many Shuttle Astronauts have been questioned after flight and there has been no admission of either visual disturbance or illusion on launch or orbit, except from one pilot. He was not motion sick and claimed an illusion of being in a static pitched-down position for several hours after orbital insertion. Great care was taken during questioning to insure that illusions and vertigo were explained and understood.

Much has been made of the 'egocentric' ability or referencing surroundings to one's own axis; for example, the ability to place the Earth above one's head rather than being inverted above the earth. Some crewmembers who were able to do this easily reported that it did not prevent SMS. Sensitivity to scenes out of alignment with one's own reference, such as inverted Earth or inverted crewmen, appears to have been disturbing to a few, but not to the majority. A common illusion may occur in experienced aircraft pilots observing the Earth while strapped in the Commander or Pilot seats with the Shuttle nose down: one feels as if it is pitching further. This may be avoided by releasing the seat belt. Dr. Lackner has reported similar experience in zero-g aircraft (19).

GASTROINTESTINAL

These signs and symptoms appeared from minutes to several hours after weightlessness and often consisted of a very brief bout of unproductive retching, but usually of sudden vomiting without nausea or other prodrome. There have been several reported episodes of vomiting, often repeated, within a few minutes of orbital insertion. One such case was observed and although sweating and pallor were absent, it is suspected that the vomiting was evoked by the launch-insertion environment (i.e., ordinary motion sickness). However, these subjects all had continuing symptoms of SMS.

Typically, vomiting due to SMS was strenuous, brief, and appeared to empty the stomach of whatever contents were present, undigested. The contents were rarely bile-stained. Subjective relief was commonly claimed afterward. In the absence of eating or drinking, these events, which produced clear vomitus, were sometimes repeated one or more times, usually with hours of spacing between events. Vomiting was not prolonged; there were no dry heaves nor frequent bouts. Typically all significant amounts of ingested food or drink were lost, usually within thirty minutes to an hour or more. The majority of subjects denied nausea, but in some this was a major symptom or a presenting symptom. This nausea sometimes waxed or waned but was not necessarily related to other activity (although some motions were avoided by SMS-affected individuals). Loss of appetite was almost universal. A variety of non-specific epigastric symptoms have been reported, the most common being a "knot in the stomach." Lower bowel functions, as judged by flatus and defecation, seemed normal.

SWEATING AND PALLOR

There was virtually no incidence of sweating, and flushing was more common than pallor. The absence of sweating cannot be attributed to the "cool, dry environment of Spacelab" (37), since it was the same environment as most test labs on Earth.

OTHER SYMPTOMS

Malaise, lack of initiative, and irritability were nearly universal during this time. Headache was common, usually mild, non-specific and with various locations in different individuals. Malaise typically increased in the first few hours and then plateaued. Somnolence was very common and may have caused brief periods of sleep given the opportunity. This was frequently a symptom which developed early and persisted until resolution. It may have been complicated by lack of usual sleep.

EFFECTS OF ACTIVITIES

Demanding activities such as the Commander's duties, the responsibility for satellite launch, or Remote Manipulator System (RMS) operations appeared to reduce the perceived discomfort, if not the actual level of SMS. Excessive movement early on orbit may have precipitated or increased the symptoms. In any event, cessation of activity, even sleeping, sometimes decreased the discomfort, but did not cure the problem.

INCIDENCE

Two interrelated questions are the incidence of SMS and the horizontal overlap of symptoms in those affected versus those unaffected. The presence of symptoms from other causes must also be considered. Incidence depends upon the criteria used and the accuracy of reporting of symptoms; estimates vary widely among investigators, from 30% to as high as 70%. While there were variations in severity with some mildly affected, there was a distinct clustering of well versus sick subjects. In some cases without frank SMS some features of the sopite syndrome were present. There was also ample stimulus available for ordinary motion sickness; e.g., vertical launch and visually inverted flight with up to 3.5G "eyeballs-in" terminating in weightlessness, plus a host of other new sensations. Consequently, diagnosis of SMS must be made with some care.

OBJECTIVE STUDIES

ELECTROOCULOGRAPHY (EOG)

Because of the unique relation between eye motion and the greater vestibular system (1,16,21), electrooculography was intensively studied (29).

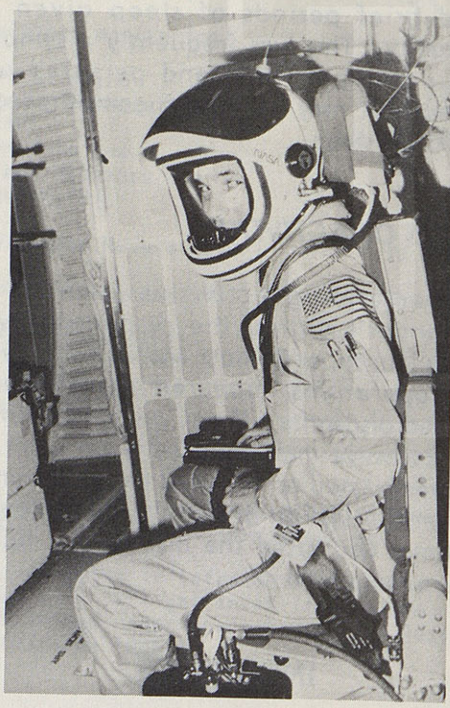

Figure 1. Crewman instrumented for EOG and recording of head position prior to launch. Data was recorded and transmitted continuously during launch and entry.

Horizontal and vertical EOG were recorded during launch on one flight and during entry on two flights, with 3 subjects. Horizontal EOG and head motion were monitored during 3 ascents and entries with a total of 4 subjects.

Conventional calibration, electrode configurations and equipment standards were employed (2,34). Standardized voluntary head oscillations with eyes open and fixed on a target, and with vision occluded by blind goggles were made before, during, and after ascent and entry. Continuous recordings were made during launch and entry (Figure 1). No abnormalities were seen, not even brief nystagmus.

On-orbit a more or less conventional EOG exam was performed (Table 2), without Hallpike maneuver or caloric stimulation, and with voluntary head oscillation substituted for an oscillating chair (Figure 2).

TABLE 2

ON ORBIT EOG PROTOCOL AND NUMBER OF PARTICIPATING SUBJECTS

Procedure	Number of Subjects (With SMS)
Gaze, Eyes open and closed, Horzontal and Vertical Deviation	17 (6)
Saccadic Tracking, Calibration	17 (6)
Head Oscillation with:	
Eyes open, fixed target	17 (6)
Eyes closed, fixed target	17 (6)
Eyes closed, shielded, Fixed Target	9 (4)
Eyes open, head synchronized target	15 (6)
Pursuit tracking, head fixed	4
Optokinetically induced nystagmus	4 (2)
Head turns	17 (6)
Head and Body Rotation - sinusoidal Eyes open, closed and shielded with fixed target	2 (2)

Again conventional standards were adhered to although the equipment had to be designed to fit the situation. Forty-one records were made on orbit, 7 during SMS, with 57 preflight and 19 postflight controls. This series can be summarized as clinically normal (29). Two isolated records contained distortion during the head oscillation which seemed most likely to be artifactual.

Figure 2. Crewman during EOG study with sinusoidal rotation on STS-8. A two axis gyroscope is mounted on the head.

AUTONOMIC NERVOUS SYSTEM RESPONSES

Another major effort was documentation of autonomic changes during SMS, including facial color, pupillary size, temperature, heart rate and blood pressure. These have proven extraordinarily difficult to obtain for non-technical reasons and there is not an adequate statistical sample to date; however, attempts continue. Objective studies of pupillary size were made by macro-photography under controlled and measured light conditions. Pallor/flushing studies were also done by photography with color control to be analyzed by chromatic micro-densitometry. Depending upon the individual, observation showed pallor or flushing with apparently normal pupillary size. Ambulatory monitoring of the heart rate and blood pressure of one subject showed them to become remarkably low as the symptoms plateaued the first day (33). Ambulatory monitoring of a subject during recovery from SMS showed a significant increase in basal heart rate during this period.

BOWEL SOUNDS MONITORING

As part of these studies, an onboard physician observed that bowel sounds were absent during the course of SMS. This finding has been subsequently confirmed by auscultation in nearly every case observed, and objectively studied (31). At least one case of hyperactive sounds during SMS with nausea and vomiting has been seen. It was possible that this hyperactivity was anti-peristaltic duodenal activity which has been seen with nausea.

Objective studies consisted of recording sounds from the right and left upper quadrants of the abdomen preflight and during and after SMS in parallel with unaffected controls. The records were semiquantitatively scored by counting the rate of audible events by standard criteria. Weightlessness did not greatly alter the rate or quality of bowel sounds in those unaffected, although some individuals may have been hyperactive the first day. Conversely, SMS greatly depressed or virtually eliminated sounds during the course of the syndrome. This phenomenon bears a constant relation to the presence of SMS. There is some evidence of rebound activity for the first hours after recovery followed by normal activity.

PERFORMANCE DURING SMS

This was the most difficult evaluation to make. Even under normal circumstances, tests of performance are, at best, tenuously related to actuality. While it is obvious that a person is hors de combat during vomiting, this is brief. Conversely, trained astronauts have in every case performed assigned tasks, though there have been two precautionary delays of scheduled EVAs. While there was a lack of initiative during SMS, tasks trained for and scheduled were done and done well. Many of these required concentration as well as good neuromuscular and eye-hand coordination. There have been cases of Payload Specialists, who have not had extensive training and mission simulations, being unable to complete all assigned tasks.

In an effort to study effects of SMS on performance, two areas have been examined: neuro-muscular performance and mental processing. The first consisted of returning hand or arm to a fixed linear position after voluntary displacement and manual tracking of a visual target on a linear scale which moved in a series of regular and aperiodic functions. A second study used the relatively common Sternberg test. This consisted of the timed indication of presence or absence of a single digit in a previously displayed number. Neither of these tests have shown any decrement in performance in the few cases examined to date.

TEMPORAL PROFILE OF SYMPTOMS

As noted, with an exception which will be treated later, onset of symptoms occurred within minutes to 1 to 2 hours of exposure to weightlessness (Figure 3). This progressed in intensity over a period of hours to a plateau which for a given condition remained stable. There were typically both head and gut symptoms although one or the other sometimes predominated. In some subjects, the gut symptoms may have been the only ones recognized, but in almost every case the gut remained quiet. Vomiting was often more frequent at the beginning. In some cases, after one or two episodes, it did not recur in the absence of intake.

The resolution of symptoms was typically sudden and dramatic, and most frequently occurred between 30 to 48 hours, but has been seen after only 12 hours, and possibly as long as 72 hours. During and after resolution there was a marked change in attitude, loss of malaise, return of stomach activity and usually appetite, and marked decrease in motion sensitivity. This typically occurred in a matter of hours or less. There was occasionally some residual motion sensitivity which decreased to normal over the next 2 to 3 days. With determined effort this sensitivity could be aggravated (37), but was not a problem with reasonable movement. Anorexia sometimes remained also, but hunger was more common. at this time or in the days immediately following, resistance to all forms of motion sickness developed. This included the out-of-plane head motions in the rotating chair as was first demonstrated in Skylab (11).

DELAYED ONSET

There was a sub-group of 4 crewmen who had significantly delayed onset of symptoms, one for 48+ hours. This crewman was very active and symptom-free for the first 2 days, yet developed a moderate case which persisted for 24+ hours. Common in these four were

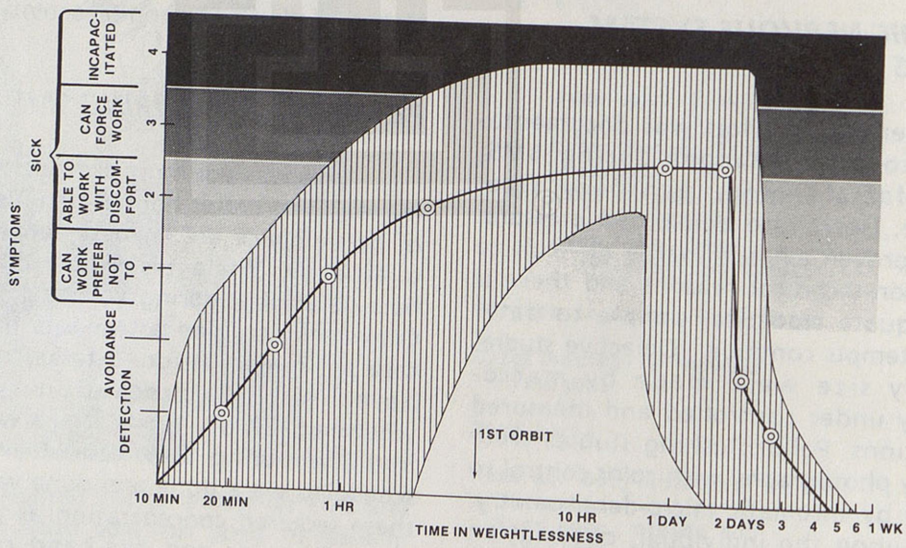

Figure 3. Time course of symptoms of SMS. The range of symptoms that have been recorded on Shuttle crewmembers is shown in the shaded area. Note that the time scale is logarithmic.

medication with ScopDex and onset of symptoms after discontinuation of the medication. This was the most convincing evidence seen to date of the efficacy of a drug to combat SMS, but it represented only a small number of subjects having taken this medication. It is probably significant that symptoms were not prevented, only delayed.

REENTRY AND POSTFLIGHT

In the American program, there have been few instances of recurring symptoms after landing, although this is reported to be common in the Russian Program (18). During reentry and for hours thereafter head turns have provoked a sense of disequilibrium in some subjects, including those not affected by SMS, but not with the sense of unpleasantness experienced by those with SMS inflight (Figure 4). One subject without SMS reported developing motion sickness symptoms on reentry while making head motions as part of an investigation. A few subjects have noted an illusion of translation during head turns hours after return to 1g. This phenomenon could not be elicited in flight from any subject including one who experienced it briefly on return. Inflight detection of motion, both angular and linear, was correct and had a nominal threshold as judged by manual movement of blindfolded crewmen without tactile stimulation.

Several changes in sensation were transiently present postflight. One of these postflight changes is an apparently delayed resistance to all forms of motion sickness or even disequilibrium. This has not been adequately studied. There have been anecdotal reports of such increased postflight resistance to unpleasant motion sensations and motion sickness, especially in aircraft, even from those who did not experience space motion sickness. One crewman repetitively tried every maneuver possible in the T-38 for 19 days after his first flight, and could elicit nothing. Two crewmen also rode the coriolis chair with head motions postflight, without any effect, although on the day of landing one had been hypersensitive to it. This lack of sensitivity appeared to last for

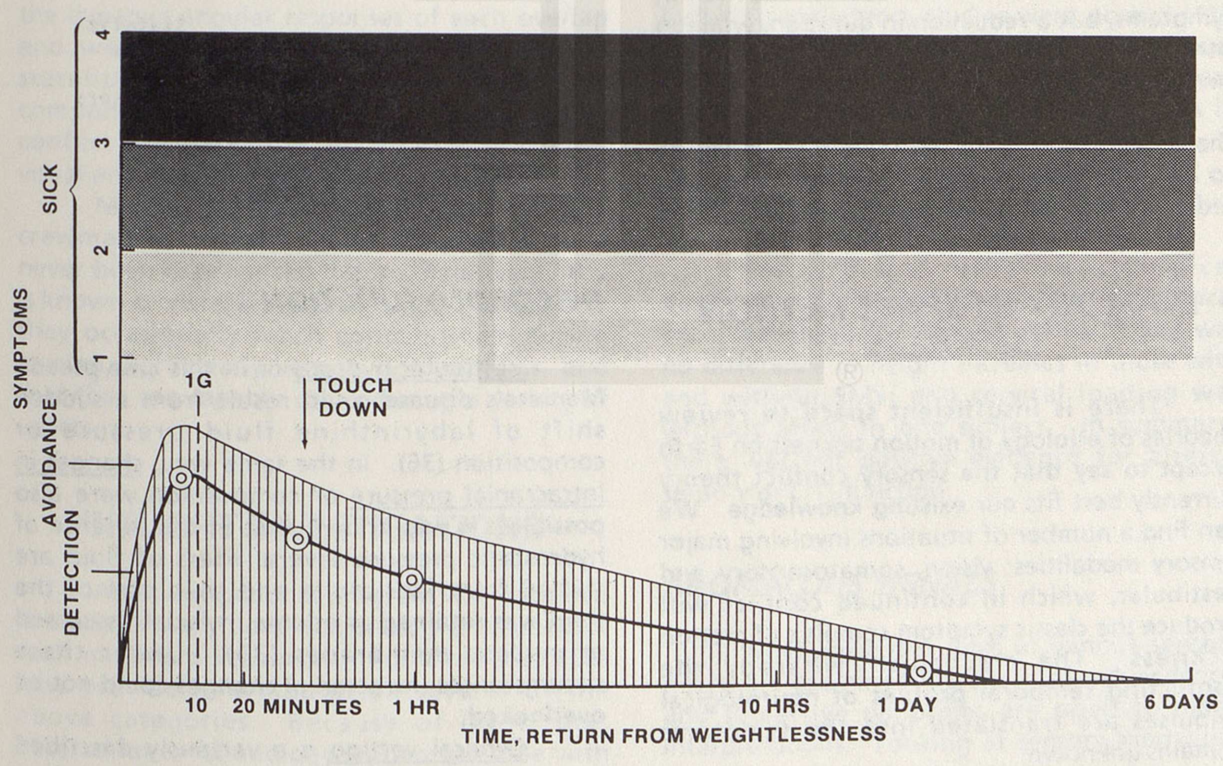

Figure 4. Time course of symptoms during neurological readaptation upon return to Earth.

weeks, but is one of many questions which need quantitative answers.

ACQUIRED RESISTANCE

The question of acquired resistance to SMS has not been adequately documented. At one time it was considered part of flight readiness to have gone through informal but vigorous acclimatization by repetitive, violent maneuvers in the T-38 and in some cases prolonged sessions in the spinning chair. Some of the subjects most resistant to motion sickness during such maneuvers suffered most from SMS.

Conversely, there is increasing evidence, largely undocumented, that prior spaceflight produces resistance to SMS. This is supported by several gastrointestinal motility studies done on individuals who have flown more than once. Previous flight appears to have no effect after a period of 10 years or more. For those who have flown within 2 to 3 years there was wide individual variation with some showing relatively small effects, even with flights as recent as 7 months, while one crewman was symptom-free on his second flight after a delay of 2+ years. In some there was no reduction in symptoms, but a reduction in duration, while in others there was a significant reduction in severity of symptoms.

It seems very significant that in no case in the American program has there been a failure to adapt to weightlessness, nor has there been redevelopment of symptoms once resolved.

ETIOLOGY OF SPACE MOTION SICKNESS

There is insufficient space to review theories of etiology of motion sickness on Earth except to say that the sensory conflict theory currently best fits our existing knowledge. We can find a number of situations involving major sensory modalities: vision, somatosensory and vestibular, which in continued conflict will produce the classic symptom complex of motion sickness. The mechanism whereby the conflicting temporal profiles of neurological impulses are translated into the symptoms remains unknown.

Significant differences between SMS symptoms and those of classic motion sickness have been seen. There are other factors to consider in SMS, such as the large and rapid cephalad fluid shifts on exposure to weightlessness (22,30,32). Taking into account the symptoms of malaise, lethargy, headache, sudden vomiting and reports of illusions, one could not reasonably exclude the possibility of malfunctioning end organs, nor even of increased intracranial pressure. At the time the inflight investigation was started a number of possible causes had to be considered and investigated (Table 3). They were based on clinical experience and a word of explanation may be in order for each.

Table 3

POSSIBLE ETIOLOGIES OF SMS

DISCORDED FUNCTION	ANOMALOUS SIGNALS
Vestibular Hydrops	Visual
Increased intracranial pressure	Vestibular
Cervical Vertigo	
	Semicircular Canals
	Statolith Organs
	Somatosensory
	Visceral

POSSIBLE CAUSES

DISCORDED FUNCTION

Vestibular hydrops or in this case pseudo Meniere's disease could result from a sudden shift of labyrinthine fluid pressure or composition (36). In the same way, changes in intracranial pressure or composition were also possible. It was known that in the absence of hydrostatic pressure several liters of fluid are shifted from legs alone and that part of the fluid was retained as edema in facial tissue and in mucous membranes (30). Under these circumstances intracranial changes could not be overlooked.

Cervical vertigo is a variously described but apparently real syndrome usually resulting from trauma to the neck's somatic sensors. This may produce vertigo, nausea and other motion sickness symptoms (5). It is known that significant expansion of the intervertebral discs occurs in weightlessness, usually beyond that seen in bed rest on Earth (28,30). There is also a change in the carrying angle of the head in weightlessness (30). These two factors could conceivably produce distortion in cervical sensors and their signals.

ANOMALOUS SIGNALS

Weightlessness can, indeed must, produce anomalous signals in some of our normal Earth-based sensory systems. There was little reason to think that it would directly affect the visual system. In many ways the visual image should remain the standard of comparison. Conversely, many correct scenes in space are inconsistent with previous experience and might well produce symptoms. For example, rapid angular maneuvers or positions incongruent with local orientation which are not possible on Earth will not have been previously experienced.

There is an inherent conflict between canal and statolith organs in weightlessness, for the dynamic angular responses of each overlap and weightlessness will grossly distort the statolith organ's signal. While the static component of this signal is correct, it will conflict with previous experience and with visual and possibly other sensory signals.

Many of the somatosensory signals a crewman encounters when weightless have never been experienced before. Relatively little is known of visceral signals beyond the fact that they occasionally reach consciousness during motion, particularly vertical accelerations, and that they are capable of producing a variety of upsets.

INFLIGHT INVESTIGATIONS

An investigational program was designed to study as many potential etiologies as possible with minimum resources. For example, EOG may provide information on several of the above categories. Because of its nature, determination of etiology was not possible with techniques currently available; rather, it was feasible to reasonably exclude most of the possibilites and focus on the most probable cause. There is not space to give the usual details of procedures or detailed results, so only summaries are offered, treating each of the potential causes listed previously.

DISCORDED CNS FUNCTION

Vestibular Hydrops

Illusions and visual field disturbances were denied; clinical neurological exam was normal; EOG exam was normal (13); there was no difference in audio threshold sensitivity or audio-evoked potentials between those affected and unaffected (13); and no significant difference was seen in volume of fluid shifted from legs in those with and without SMS.

Increased CNS Pressure

Illusions and other neurological disturbances were denied; clinical neurological exam was normal; there were no changes in fundus; EOG was normal (13); one intraocular pressure was normal; audio evoked potentials including midlatency studies were normal (13); eye-hand tracking was normal; one visual evoked potential was normal; and no difference was seen in fluid volume shifted from legs in those with and without SMS (22).

Cervical Vertigo

Illusions and other neurological disturbances were denied; clinical neurological exam was normal; EOG was normal; there was no difference in height increases in those with and without SMS; and cervical loading was without affect in one subject. In summary, there was not positive evidence for altered sensory or CNS function.

ANOMALOUS SIGNALS

When potential roles of various sensory inputs are examined there is less hard evidence, and subjective symptoms are open to many interpretations. Looking at sensory modalities for effects of weightlessness:

Visual

Visual disturbances were denied, and visual acuity and extraocular motion were normal, as were reflexes to light and accommodation. The visual tracking function for saccadic, pursuit and nystagmoid motion was normal, as was optokinetic nystagmus; i.e., the purely visual inputs were normal. The absence in this study of oscillopsia, or pathological nystagmus, and the ability to normally track a head-synchronized target during SMS argue against other sensory modalities disturbing visual function; i.e., the visual information should be valid.

Vestibular Function

Canal function appeared to be normal, for while there were changes in VOR gain as could be determined from eyes occluded head oscillation, the differences appeared random in time and between subjects. The strongest evidences for the role of vestibular inputs were the overwhelming conscious sensations that occurred during motions. In many, the pitch plane was most sensitive while in others it was yaw, but in any event it was a potent sensation. Stopping all motion sometimes caused some improvement in feeling, but it did not cure SMS, and there is evidence from gastrointestinal studies to support this. Stopping motion probably only removed the unpleasant sensations from motion and had little objective effect on the underlying process. An example of this is one subject who simply clung to a supporting structure with eyes closed for two nights and a day without improvement.

Somatosensory Inputs

The only direct studies of this system were the kinesthetic position sense and eye-hand tracking. These did not look at senses which would most likely be involved in gravity produced signals, hence it could be argued they are irrelevant. The number of studies during SMS are small and not statistically significant to date, but no significant changes have been seen in performance during or after SMS. One subject was loaded to the equivalent of his own weight by the treadmill harness and stood quietly for a prolonged period without improvement in symptoms.

Visceral Inputs

No means were available to study this. Other than the gastric symptoms noted, visceral sensation did not reach consciousness.

In summary, this study showed no evidence for the role of altered or disturbed sensory or neurological systems and considerable evidence against such. At the same time there is strong theoretical argument for a sensory conflict between the canal and statolith organ signals. This argument is consistent with the phenomena observed. Visual signals are not altered and should be consistent with canal signals, both of which conflict with dynamic statolith signals. Visual scenes may produce conflicts with stored information from previous experience or possibly with static information from statoliths or somatosensory signals. The role of somatosensory or visceral inputs is unknown.

Neuroanatomy also seems to be consistent with a major role for vestibular conflict since there are known pathways, through nuclei, connecting the end organs to the one area which is consistently affected by SMS, the upper gastrointestinal tract (28,32). It may be significant that the vestibular nuclei, the nuclei which control the digestive tract, the chemoreceptor trigger zone, and the emesis center are in very close proximity around and under the 4th ventricle.

CONCLUSION

COMMENT

The current problem is ignorance of basic mechanisms. The pathways and the nature of the signals that cause the ileus of the upper gastrointestinal tract and the head symptoms are unknown. There are two basic possibilities: neurological transmission and/or humoral transmission. This remains an open question. While it is felt that the neurological pathway is more likely, nevertheless serum has been collected in a search for strange agents. One subject received an injection of naloxone, an opioid blocker, during SMS without effect.

The question of whether or not cerebral spinal fluid might be a pathway has been raised by one set of experiments. This certainly deserves consideration.

An important aspect of these investigations was the demonstration that useful, objective data can be gathered quickly and with minimum resources during operational missions.

SUMMARY

Space Motion Sickness is a probable variant of 1g motion sickness with major differences in many aspects. It has not been incapacitating to trained individuals, who have still performed demanding tasks with it. It has been universally self limiting in the American experience, usually clearing within 36 hours. It has not recurred on continued exposure, and appears to be moderated by repeated experience. It appears to have produced an upper gastrointestinal ileus in almost all of those affected and vomiting has been secondary to this ileus, not a primary event. Restriction of food and drink has helped to minimize vomiting.

At this time it appears that an intra-vestibular conflict is the primary cause with unknown contributions from other modalities. Current knowledge of the neuronal mechanisms in volved is inadequate for understanding the process. Some breakthrough, some drug, or some method of stimulating the conflict on Earth might be found, but until then SMS must be studied in the only place it occurs - space.

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Section Six
Vision

This crewman is performing a DSO to test for changes in near-vision acuity. An understanding of visual function changes due to microgravity is important for on-orbit operations.

EFFECTS OF SHORT-TERM SPACE FLIGHT ON SEVERAL VISUAL FUNCTIONS

Investigators: H. Lee Task, Ph.D., and Col. Louis V. Genco

INTRODUCTION

Since the early days of the Gemini space program there has been an interest in the possible effects of the space environment on visual capability. During the Gemini program S.Q. Duntley headed an effort to determine the effects of space on visual acuity at two different contrast levels. His approach was to develop a portable, compact vision tester to fly aboard the Gemini capsule and compare these results with the astronauts' ability to see similar target patterns constructed on the ground. These methods provided limited visual acuity data on a total of 4 astronauts.

Duntley originally planned to measure a number of visual functions, but due to various limitations only the visual acuity under two contrast conditions was measured. Very little quantitative work on vision in space has been done since that time.

In order to explore the area of vision in space, a series of visual function testers (VFT) was developed to measure several visual functions. The first of these (VFT-1) measured visual acuity, stereopsis, torsional phoria, lateral and vertical phoria, critical fusion frequency and eye dominance. VFT-2 was designed to measure contrast thresholds for several types of optical patterns.

These first two VFTs were flown on several shuttle flights. A total of 16 astronauts have been tested on VFT-1 and 5 have been tested on VFT-2.

PROCEDURES / RESULTS

VFT-2: MEASUREMENT OF CONTRAST SENSITIVITY

VFT-2 was designed to measure visual contrast threshold for several test patterns. The amount of contrast required to see a pattern or to extract specific information concerning the pattern (e.g. orientation) increases as the size of the pattern (or information detail) becomes smaller. A standard method of presenting this data is to take the reciprocal of the contrast (designated contrast sensitivity) and graph it against the reciprocal of size (spatial frequency).

The observer was instructed to increase the contrast of the pattern until the specified detail was detected. At this point, readings of the luminance values of the target pattern and background were taken with internal light sensors. This insured accurate calibration of the instrument.

Four types of test patterns were employed. Six upper squares each contained a square-wave pattern of a single spatial frequency (light & dark bars per degree of visual angle). The six spatial frequencies tested were: 4, 8, 12, 16, 22 and 30 cycles per degree. The lower left square contained an array of tri-bar targets with 8 spatial frequencies represented (the 8 rows) and 8 tri-bars at each spatial frequency in random orientations (vertical or horizontal). The lower center square was a continuous resolution fan test pattern ranging from 10 to 70 cycles per degree and the lower right square contained Blackwell disks of six different sizes (six rows).

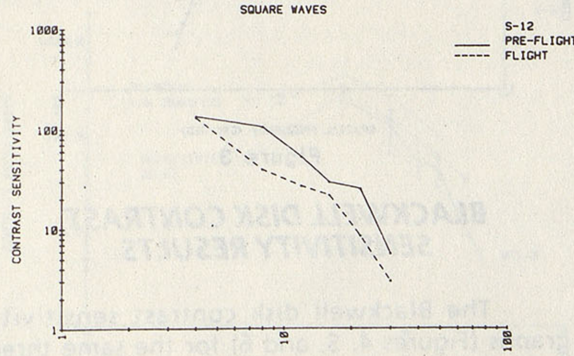

Figure 1

SQUARE-WAVE CONTRAST SENSITIVITY RESULTS

Figures 1, 2, and 3 show the square-wave contrast sensitivity for the three astronauts who participated in the use of the VFT-2. Subjects S-12 and S-15 tended to show a decrease in square-wave contrast sensitivity during flight compared to pre-flight tests while S-13 showed a minor improvement in contrast sensitivity during flight compared to pre-flight. As a group, there was no statistically significant change in contrast sensitivity during spaceflight compared to the pre-flight baseline. Further investigation is required to determine if the individual changes are significant and repeatable.

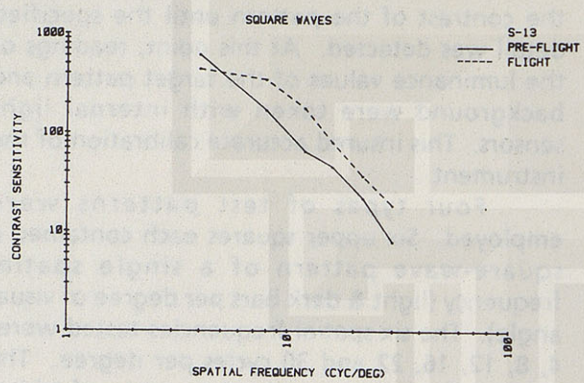

Figure 2

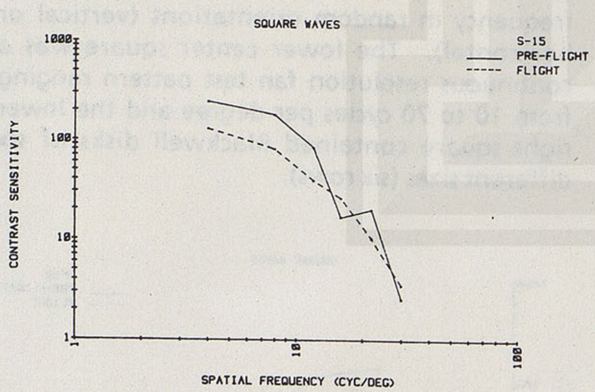

Figure 3

BLACKWELL DISK CONTRAST SENSITIVITY RESULTS

The Blackwell disk contrast sensitivity graphs (Figures 4, 5, and 6) for the same three subjects show results that are very similar to the square-wave contrast sensitivity. Again S-12 had a lower contrast sensitivity during flight than pre-flight. S-15 showed essentially no difference between the two conditions. The overall group results indicate that there is no significant group effect due to space flight. Again, further research is required to determine if the individual changes are repeatable.

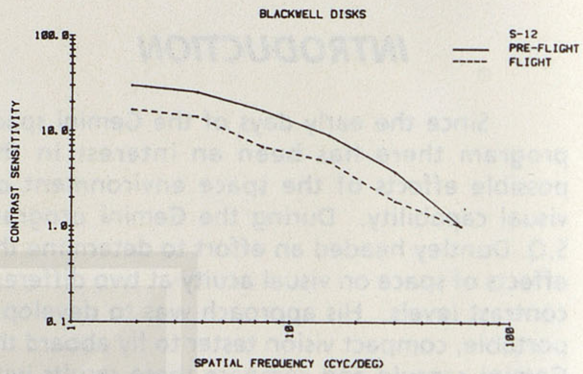

Figure 4

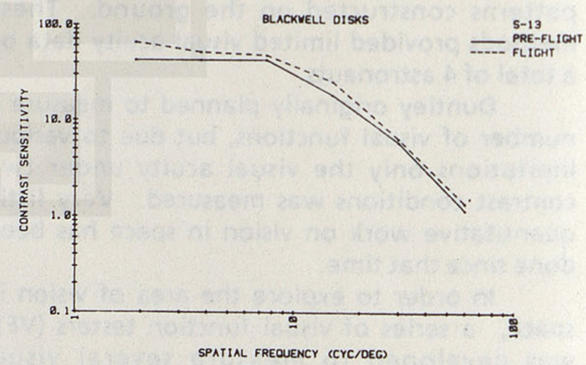

Figure 5

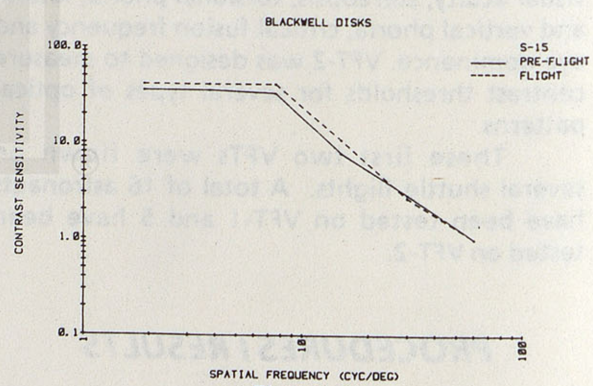

Figure 6

TRI-BAR CONTRAST SENSITIVITY RESULTS

The tri-bar results are highly similar to the Blackwell disk and square wave contrast sensitivity results as can be seen from the graphs

(Figures 7, 8, and 9). One significant finding from this study so far is that the results from the different test pattern types are so close that future study in this area need only use one of the pattern types to investigate changes in contrast sensitivity. Since the Blackwell disks or tri-bars require much less space than the square-wave patterns and yield the same results, it is most probable that future efforts will concentrate on one of these two pattern types.

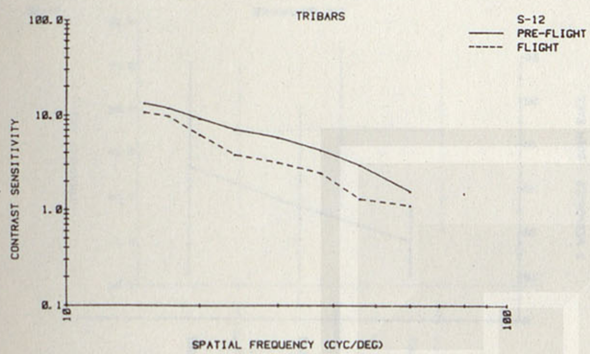

Figure 7

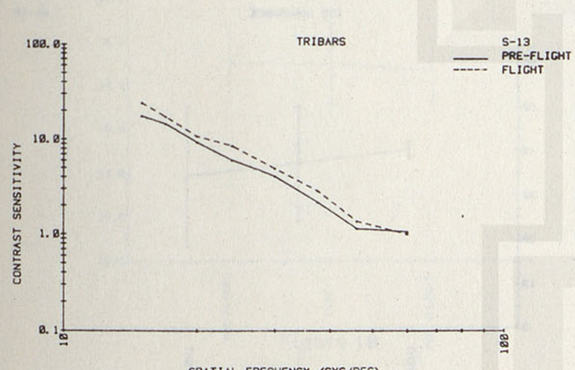

Figure 8

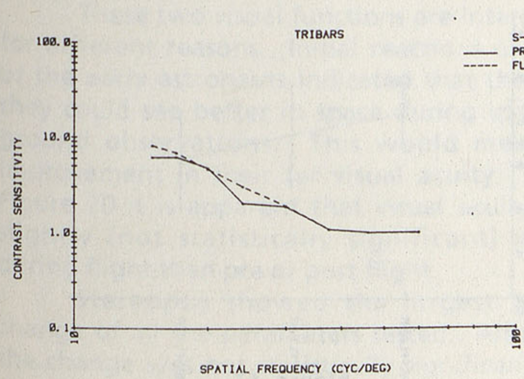

Figure 9

VFT-2 COMPARISON WITH OTHER CONTRAST SENSITIVITY MEASUREMENT METHODS

Figures 10 and 11 show a comparison between contrast sensitivity measured using the square-wave test patterns of VFT-2 and two other methods using sine-wave test patterns. The Optronix y/n tracking method uses a TV display to produce a sine-wave test pattern to which subjects respond. The other method uses a photographically printed array of sine-wave patterns of different contrasts and spatial frequencies. The graphs below show a good correspondence between the VFT-2 measurement and the photographic charts method. The specific TV method used resulted in somewhat higher measures of contrast sensitivity as evidenced by the graphs below. These graphs are part of a validation study that was conducted to compare the VFT-2 methods of measuring contrast sensitivity with other methods.

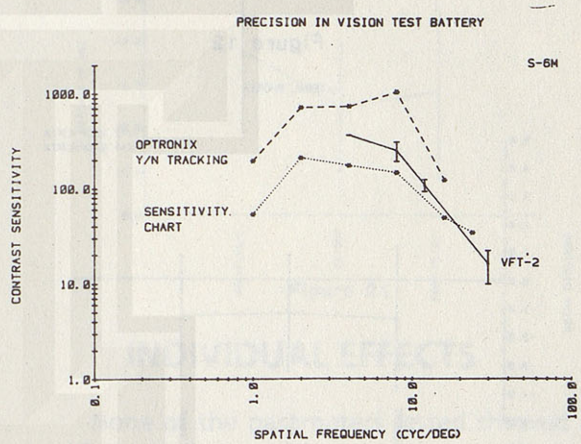

Figure 10

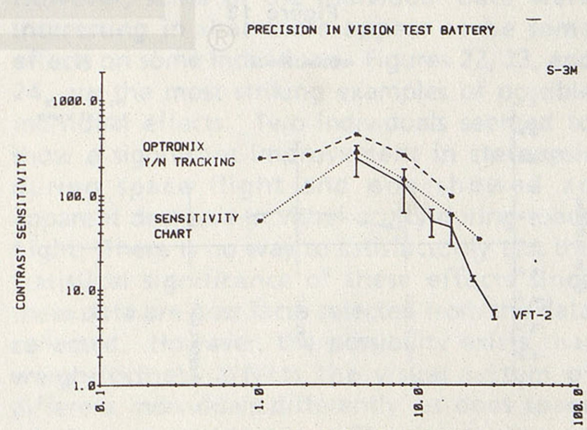

Figure 11

PHORIA OR EYE MUSCLE BALANCE RESULTS

Figures 12, 13, and 14 summarize the results of eye muscle balance effects due to space flight for all 15 astronauts tested. There was no significant group effect for cyclophoria, vertical phoria or horizontal phoria. Additionally, there did not appear to be any evidence of individual changes in eye muscle balance due to weightlessness.

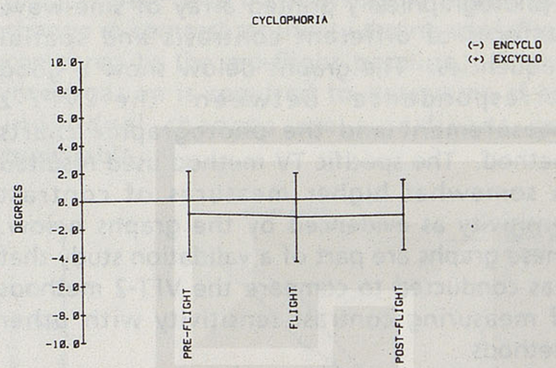

Figure 12

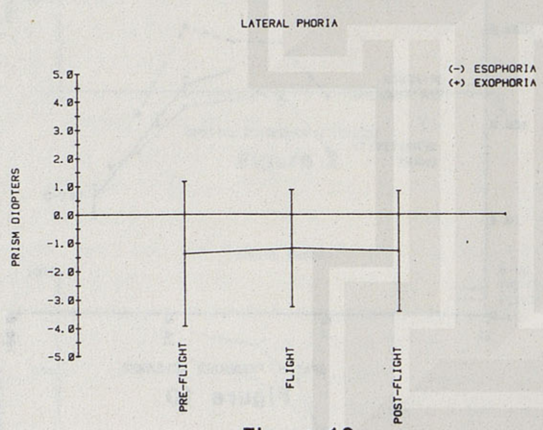

Figure 13

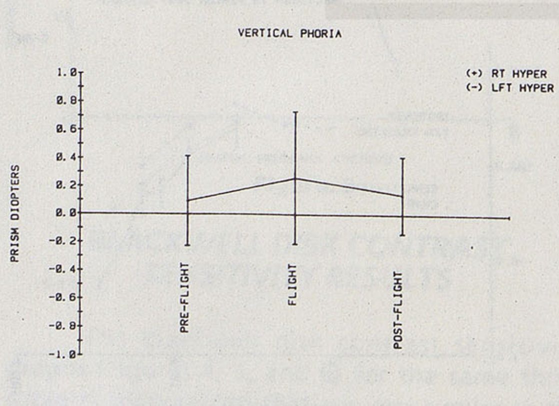

Figure 14

EYE DOMINANCE

The change in eye dominance as measured by the VFT-1 was not statistically significant. The changes evident on the graphs (Figures 15, 16 and 17) may have been a result of repeated exposure to the method of testing (essentially learning). As noted on the graphs, data for this test was only available for six astronauts: S-1 to S-6.

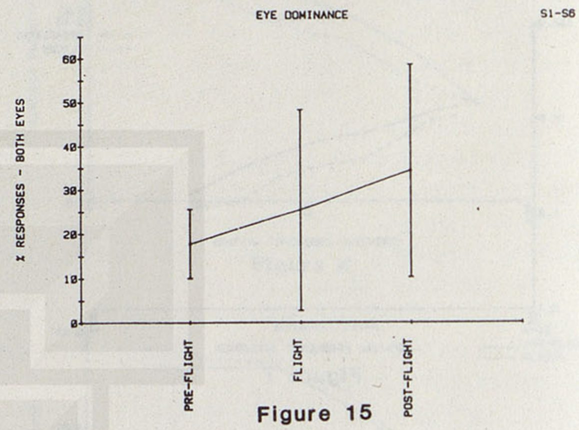

Figure 15

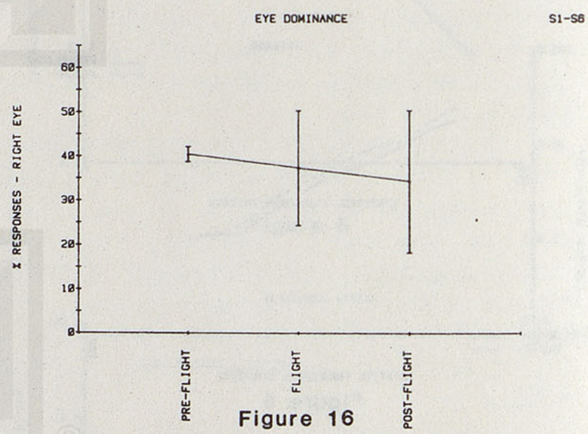

Figure 16

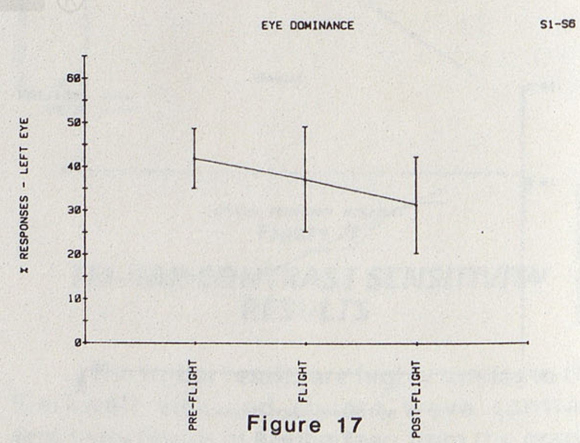

Figure 17

CRITICAL FLICKER FREQUENCY

The critical flicker frequency was measured both foveally (center of the retina) and peripherally (about 15 degrees off center) for all astronauts. As is obvious from the graphs (Figures 18 and 19), there were no significant changes in either of these parameters due to weightlessness.

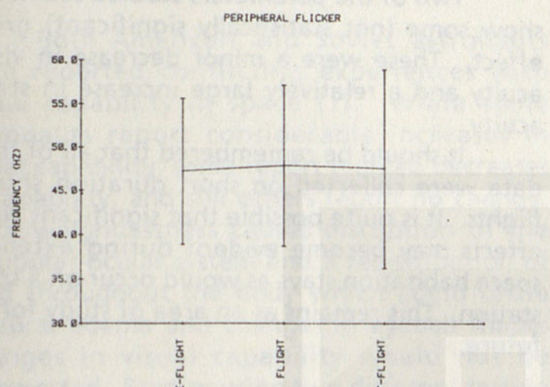

Figure 18

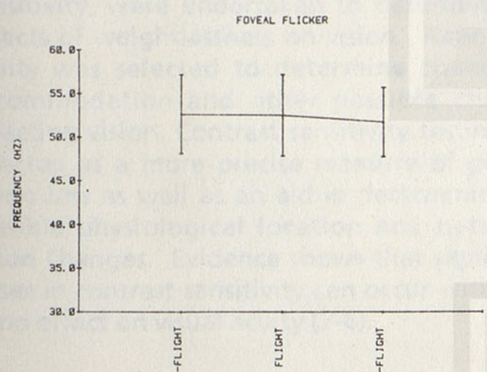

Figure 19

STEREOPSIS AND ACUITY

These two visual functions are interesting for different reasons. Initial reactions of some of the early astronauts indicated that they felt they could see better in space during space to ground observations. This would mean an improvement in their far visual acuity. From Figure 20 it is apparent that visual acuity was slightly (not statistically significant) worse during flight than pre or post flight.

Stereopsis showed the largest group change of all the parameters tested. Although the change was not statistically significant, the change was particularly interesting because it shows an apparent improvement in stereo acuity due to space flight. There is no explanation nor any hypothesis of a mechanism for why this might occur.

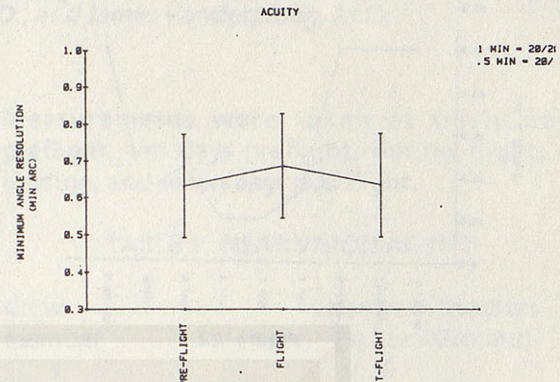

Figure 20

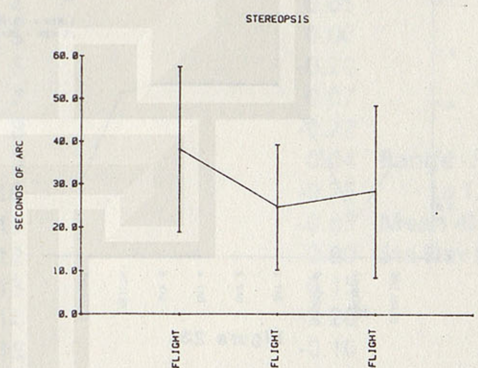

Figure 21

INDIVIDUAL EFFECTS

None of the parameters tested showed a significant change due to space flight. However, some of the individual data were interesting in that there appear to be some effects on some individuals. Figures 22, 23, and 24 are the most striking examples of possible individual effects. Two individuals seemed to show a significant improvement in stereopsis during space flight and one showed an apparent decrease in visual acuity during space flight. There is no way to satisfactorily test the statistical significance of these effects since these data are post facto selected from the data collected. However, the possibility exists that weightlessness affects the visual system of different individuals differently, as does space adaptation syndrome. The best way to determine if the graphs are significant is to retest these subjects on future flights if the opportunity arises.

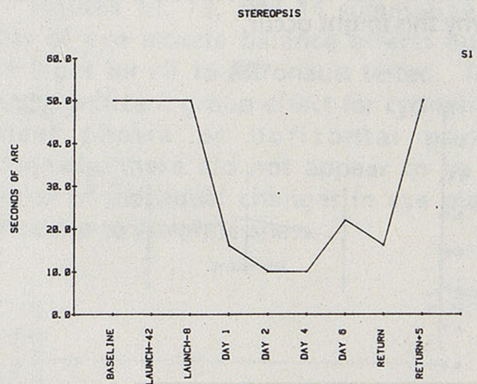

Figure 22

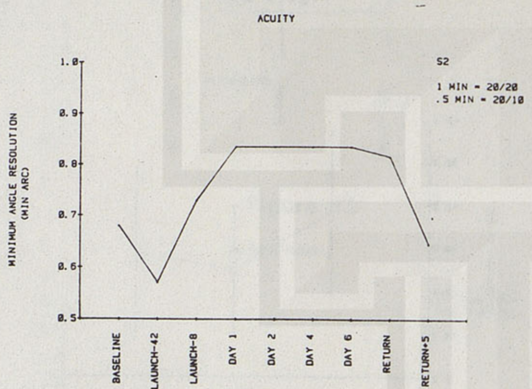

Figure 23

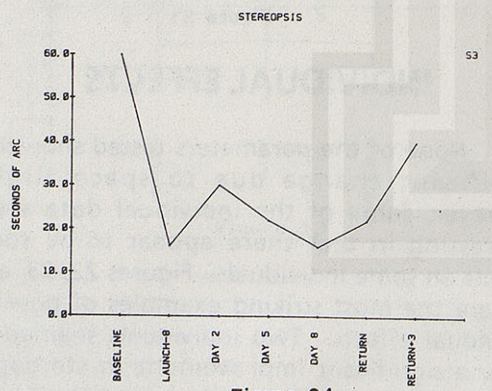

Figure 24

CONCLUSIONS

The VFT-1 and VFT-2 tested for changes in visual acuity, stereopsis, vertical and lateral phoria, cyclophoria, critical flicker frequency, eye dominance and contrast sensitivity. None of these visual parameters showed a statistically significant group change due to weightlessness. A total of 15 astronauts participated in VFT-1 experiments and 3 in the VFT-2 study.

Although there were no group changes in these parameters, some individuals appeared to show significant differences in acuity and stereopsis during space flight. Without further study it is impossible to determine if these effects are real or simply a happenstance of the data.

Two of the parameters studied seemed to show some (not statistically significant) group effect. These were a minor decrease in visual acuity and a relatively large increase in stereo acuity.

It should be remembered that all of these data were collected on short duration shuttle flights. It is quite possible that significant visual effects may become evident during extended space habitation stays as would occur on a space station. This remains as an area of study for the future.

VISION IN SPACE: NEAR VISION ACUITY AND CONTRAST SENSITIVITY

Investigators: Arthur P. Ginsburg, Ph.D., and James Vanderploeg, M.D.

INTRODUCTION

Both American and Soviet astronauts have reported conflicting experiences with visual capability in space (1). While some astronauts report considerable increases in visual capability, some report marked decreases in capability, and still others report no change. Since weightlessness causes disruption of the vestibular-ocular system and a redistribution of fluid throughout the body which could cause cerebral edema and changes in eyeball shape, changes in visual capability would not be unexpected. Studies using two different testing methods, near visual acuity and contrast sensitivity, were undertaken to determine the effects of weightlessness on vision. Near visual acuity was selected to determine changes in accommodation and other possible changes affecting vision. Contrast sensitivity testing was selected as a more precise measure of general vision loss as well as an aid in determining the possible physiological location and nature of vision changes. Evidence shows that significant losses in contrast sensitivity can occur with little or no effect on visual acuity (2-6).

PROCEDURES

Twenty-three crew members were tested for near vision acuity. Sixteen crew members were evaluated for contrast sensitivity. Using the near point of accommodation, near vision acuity was measured in diopters from a Krimsky rule. Contrast sensitivity was measured using five specially designed contrast sensitivity charts. The contrast levels and orientations of the test patches for each chart were randomized to control for guessing and memorization. Six spatial frequencies of 1, 2, 4, 8, 12, and 24 cycles per degree were tested at a distance of 18 inches. Luminance differences between ground and space testing were controlled

Measurements were taken at thirty days preflight, ten days preflight, during flight, at landing, and seven days postflight.

TABLE 1. NEAR VISION ACUITY

Crew-member	Change in Diopters (Space - Ground)	
1	0.20	
2	1.20*	
3	-0.45	
4	0.05	
5	0.00	
6	-0.20	
7	0.07	
8	-0.22	
9	0.04	Range -2.2
10	-0.25	to 1.45
11	-0.83	Mean -0.068
12	-0.80	Std Dev 0.74
13	0.15	
14	-2.20*	
15	-0.10	
16	0.20	
17	-0.45	
18	-0.47	
19	1.45*	
20	0.20	
21	1.10*	
22	-0.40	
23	0.15	

*Clinically Significant (>1 Diopter Change)

RESULTS

Near vision acuity data were analyzed for differences in the near point of accommodation among the preflight, inflight, postflight, and average of pre- and postflight measurements (Table 1). Paired t-tests and analysis of variance with repeated measurements showed that no significant differences in diopter measurements existed among the three phases of flight. Contrast sensitivity data were analyzed for differences between the average preflight contrast sensitivity data and those obtained inflight, at landing, and postflight (Figure 1). Statistically significant individual differences in contrast sensitivity changes in space were found. Crewmembers exhibited different magnitudes of change at different spatial frequencies.

CONCLUSIONS

No clinically significant changes in near vision acuity in the micro-gravity environment of space were found during space shuttle flights. However, changes in contrast sensitivity were seen under these conditions. Alterations in contrast sensitivity occurring in the low and middle but not the high spatial frequencies cannot be readily attributed to changes in accommodation, but reflect more central effects. In general, the changes in contrast sensitivity are less than a factor of two and would not be expected to cause major visual performance increases or decreases. The possible physiological reasons for the changes in contrast sensitivity during space flight will require further research.

Figures 1 - 6. Changes in contrast sensitivity of crewmembers from initial (baseline) measurements. The data of these six crewmembers are typical of the largest changes found. Note that there are significant increases and decreases in sensitivity over different spatial frequencies for these crewmembers. Further research will be required to fully understand these changes. Since these changes are generally a factor of two or less, no major visual gains or losses are indicated for crewmembers in space.

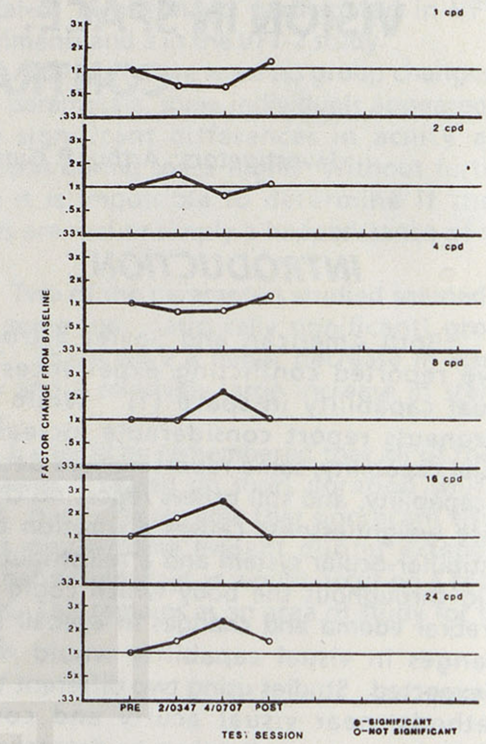

Figure 1. Crewman A.

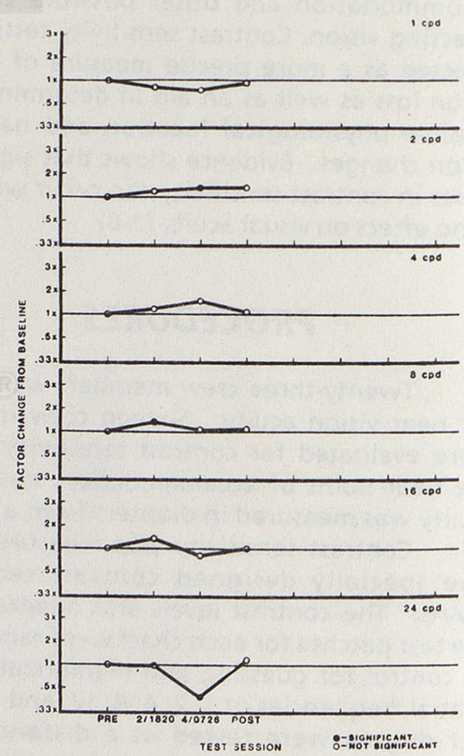

Figure 2. Crewman B.

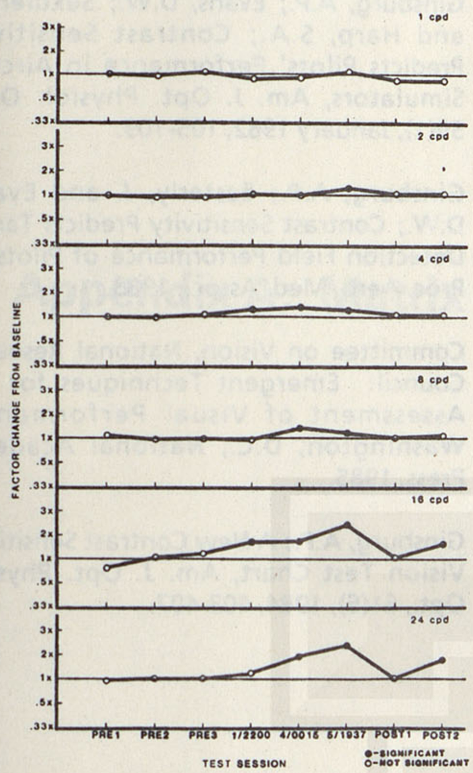

Figure 3. Crewman C.

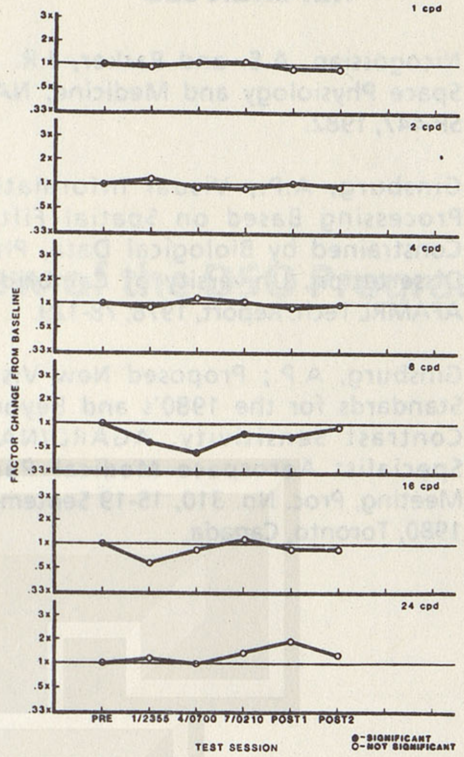

Figure 5. Crewman E.

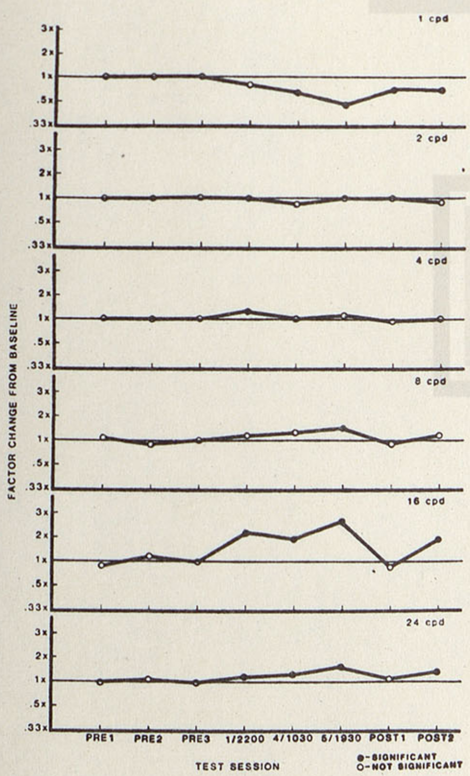

Figure 4. Crewman D.

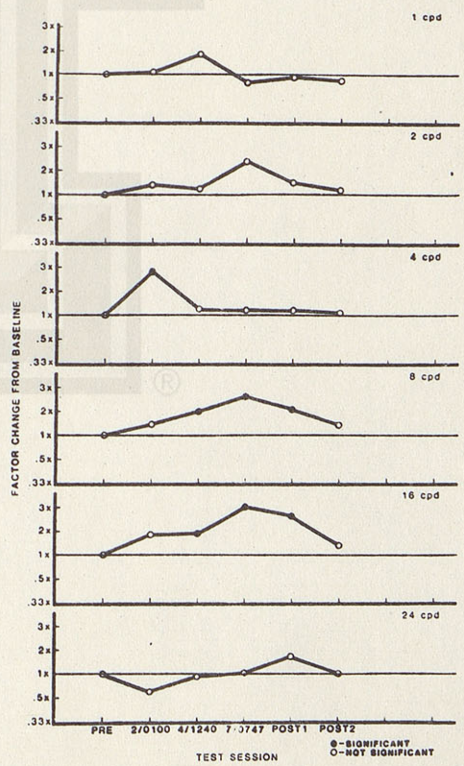

Figure 6. Crewman F.

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6. Committee on Vision, National Research Council: Emergent Techniques for the Assessment of Visual Performance, Washington, D.C., National Academy Press, 1985.

7. Ginsburg, A.P.; A New Contrast Sensitivity Vision Test Chart, Am. J. Opt. Physiol. Opt., 61(6), 1984, 403-407.

Appendix A: Matrix Overview of the DSO Program

MATRIX 1: MEDICAL DSOs LISTED BY NUMBER AND TITLE Prepared 02-20-87 by SBRI Flight Projects/MAB

DSO	TITLE	INVESTIGATOR(S)	FLIGHT HISTORY	COMPLETION STATUS	SUMMARY OF RESULTS
401	Validation of Predictive Tests and Countermeasures for Space Motion Sickness	Dr. J. L. Homick	Performed on 16 missions: STS-1 through 9, 41B, 41C, 41D, 41G, 51A, 51C, & 51D	This study is complete. All 58 requested subjects were obtained.	Predicting susceptibility to SMS by using ground based test results is difficult, but shows some promise. Reporting of SMS symptoms is now SOP on all Shuttle flights. See page 153 of this report.
402	Cardiovascular Deconditioning Countermeasure Assessment	Dr. M. W. Bungo and Dr. P. C. Johnson	12 Flights: STS-1 thru 9, 41B, 41C, 41D	This study is complete. All 46 requested subjects were obtained.	Prelanding "fluid loading" is an effective countermeasure for orthostatic intolerance. Fluid loading prior to reentry has been made SOP on all Shuttle flights. See page 41 of this report.
403	Head and Eye Motion During Ascent and Entry	Dr. W. E. Thornton	STS-5 through 8 (4 Flights)	Complete; all 5 requested subjects were obtained.	No abnormalities have been seen with or without SMS. See pages 162 and 167 of this report.
404	On-Orbit Head and Eye Tracking Tasks	Dr. W. E. Thornton	STS-5 through 8 (4 Flights)	Complete; 16 subjects were obtained.	No evidence of disordered and organs or of increased CNS pressure. See pages 162 & 167 of this report.
405	Acceleration Detection Sensitivity	Dr. W. E. Thornton	STS-5, 7, and 8 (3 Flights)	Complete: 2 subjects were obtained.	Hardware performance was inadequate; undesired angular oscillations made detection of linear motion questionable.
406	Kinesthetic Ability	Dr. W. E. Thornton	STS-5, 7, and 8 (3 Flights)	Complete; 3 or 4 subjects obtained.	No conclusions were reported.
407	Photographic Documentation of Body Fluid Shift	Dr. W. E. Thornton	STS-6, 7, and 8	Complete; 7 subjects obtained.	Photographs are adequate, but analysis is incomplete.
408	Near Vision Acuity and Contrast Sensitivity	Drs. A. Ginsberg & J. M. Vanderploeg	Nine flights: STS-5, 6, 7, 8, 41B, 41C, 41D, 41G and 51C	Complete; 32 of 36 requested subjects were obtained.	Some changes in contrast sensitivity were observed; changes in acuity were insignificant. See page 179 of this report.
409	Microbial Screening	Dr. D. L. Pierson	Four flights: STS-6, 7, 8, and 41B	Complete; data was collected on 4 flights as requested.	A continual buildup of airborne contaminants was demonstrated. See page 93 of this report.

MEDICAL DSOs LISTED BY NUMBER AND TITLE (Continued)

DSO	TITLE	INVESTIGATOR(S)	FLIGHT HISTORY	COMPLETION STATUS	SUMMARY OF RESULTS
410	Audiometry	Dr. W. E. Thornton	STS-6, 7, and 8	Complete; 13 subjects were obtained.	Results are questionable. Audio evoked potentials are preferred to this method.
411	Simple Mass Measurement	Dr. W. E. Thornton	STS-8	Complete; 1 subject was obtained.	Concept is valid, but balance time constant was too long for accurate measurements.
412	Treadmill Operation	Dr. W. E. Thornton	STS-7 and 8	Complete; 2 subjects obtained.	Data points were incompatible with analysis procedure.
413	Cell Attachment in Microgravity	Dr. D. R. Morrison	STS-7	Complete	Cells can attach to a growth surface in microgravity. (This study continued with an incubator as DSO 432.) See page 85 of this report.
414	Ophthalmoscopy	Dr. E. L. Shulman	STS-7 and 8	Complete; 4 subjects were obtained.	No indication of increased intracranial pressure. See page 167 of this report.
415	Tissue Pressure Tonometry	Dr. W. E. Thornton	STS-7 and 8	Complete; 5 subjects obtained.	Data were nominally obtained. See page 160 of this report.
416	Ambulatory Monitoring	Dr. W. E. Thornton	STS-7 and 8	Complete; 2 subjects obtained.	Bowel sounds may be reliable as a "marker" for SMS. See page 163 of this report.
417	Inflight Countermeasures for SAS	Dr. W. E. Thornton	STS-7 and 8	Complete; 1 subject obtained.	Physical countermeasures seemed to have little effect, yet one pharmacological agent initially showed great promise. See page 134.
418	Eye-Hand Coordination	Dr. W. E. Thornton	STS-8	Complete; 5 requested subjects obtained.	No obvious changes were noted. See page 164 of this report.
419	Evaluation of Food Flavor Perception in Zero Gravity	R. L. Sauer	---	Disapproved	---
420	Evaluation of Taste Acuity in Zero-g	R. L. Sauer	---	Disapproved	---

MEDICAL DSOs LISTED BY NUMBER AND TITLE (Continued)

DSO	TITLE	INVESTIGATOR(S)	FLIGHT HISTORY	COMPLETION STATUS	SUMMARY OF RESULTS
421	Animal Enclosure Module Inflight Test	Dr. M. C. Smith	STS-8	Complete; data was collected on 1 flight as requested.	Six rats were successfully kept healthy without impairing the safety of the crew. See page 75 of this report.
422	Anatomical Observation	Dr. W. E. Thornton	STS-8	Complete; all 5 requested subjects were obtained.	Many changes were noted using auscultation and palpation; percussion was not possible.
423	Study of Inflight Fluid Changes	Drs. W. E. Thornton and C. S. Leach	STS-8	Complete; 1 subject was obtained as requested.	Fluid shift of up to 4 liters occurs within hours of exposure to zero gravity.
424	Evoked Potentials	Dr. W. E. Thornton	STS-8	Complete; 4 subjects obtained as requested.	No evidence of abnormalities was found. See pages 160 & 167 herein.
425	Intraocular Pressure	Dr. S. L. Pool	STS-8	Complete; 1 subject obtained as requested.	No apparent difference from preflight. See pages 160 & 167 herein.
426	Denitrogenation Procedures Validation	J. M. Waligora and D. J. Horrigan	---	Withdrawn	---
427	Soft Contact Lens Application Test	Drs. W. E. Thornton and L. R. Young	STS-8	Complete; 1 subject obtained as requested.	Lens would not adhere using the prescribed procedure.
428	Unassigned	---	---	---	---
429	Unassigned	---	---	---	---
430	Unassigned	---	---	---	---
431	Unassigned	---	---	---	---
432	Engineering Test of Carry-on Incubator and Cell Attachment in Microgravity	Drs. D. R. Morrison and A. Cogoli	STS-8	Complete; data was collected on 1 flight as requested.	Cell attachment inflight was greater than in ground control samples and much improved over DSO 413 results; there are exciting implications for bioprocessing in space. See page 87 of this report.

MEDICAL DSOs LISTED BY NUMBER AND TITLE (Continued)

DSO	TITLE	INVESTIGATOR(S)	FLIGHT HISTORY	COMPLETION STATUS	SUMMARY OF RESULTS
433	Preflight and Postflight Parallel Swing Tests	Drs. D. E. Parker and M. Reschke	STS-8, 41B, and 51D	Complete; 5 of 6 requested subjects obtained (including those obtained as part of DSO 449).	Findings support the Otolith Tilt-Translation Reinterpretation Hypothesis. Was renamed DSO 449 prior to STS-51D. See page 145 of this report.
434	Unassigned	---	---	---	---
435	Unassigned	---	---	---	---
436	Inflight Monitoring as a Reflection of Cardiovascular Deconditioning	Dr. M. W. Bungo	---	Withdrawn	---
437	Microbial Monitoring	Dr. D. L. Pierson	STS 51-B	Active; data has been collected on 1 flight and is to be collected on all flights with animals.	Adherence to the Specific Pathogen Free criteria for animals protected the crew when the RAHF failed. See page 97 in this report.
438	Unassigned	---	---	---	---
439	Documentation of the Action of Metoclopramide	Dr. W. E. Thornton	STS-41D, 41G, 51C, 51D*, 51B	Complete; 9 of 12 requested subjects were obtained.	SMS causes cessation of bowel activity. MCP is an ineffective treatment. See page 138 in this report.
440	Crew Visual Performance	Lt. Col. L. V. Genco and Dr. H. L. Task	STS-41D, 41G, and 51C	Complete; 10 of 11 requested subjects were obtained.	Acuity is marginally poorer; stereopsis shows marked improvement. All values tend toward norms on return. See page 173 herein.
441	Blood Pressure Monitoring During Reentry	Drs. W. E. Thornton and T. P. Moore	STS-8, 41D, 41G, 51C, 51D*, 51B, and 51F	On hold; 9 of 9 requested subjects were obtained.	No evidence of orthostatic hypotension during the flight phase; there are questions about the seat egress phase. See page 37 herein.

*As part of DSO 456.

MEDICAL DSOs LISTED BY NUMBER AND TITLE (Continued)

DSO	TITLE	INVESTIGATOR(S)	FLIGHT HISTORY	COMPLETION STATUS	SUMMARY OF RESULTS
442	Autogenic Feedback Training (AFT)	Dr. P. S. Cowings	STS-51C	Complete; 1 subject was obtained as requested.	Provided valuable suggestions for improvement of hardware and procedures for the AFT experiment on Spacelab 3. See page 79 herein.
443	Seqmental Fluid Shift	Drs. J. S. Logan, R. J. Luciani, L. D. Montgomery, and G. R. Coulter	---	On hold	---
444	Unassigned	---	---	---	---
445	Thoracic Impedance Measurements	Drs. T. P. Moore and W. E. Thornton	STS-8 (not as 445)	On hold; 1 subject was obtained.	No conclusions were reported.
446	Leg Plethysmography	Drs. T. P. Moore and W. E. Thornton	STS-51B, 51D*, and 51J (as DSO 446); 61B and 61C (as DSO 461)	Complete; 9 of 8 requested subjects were obtained (including those obtained as part of DSO 461).	There is typically a 1 liter volume change in each leg, largely due to shifts in body fluids. The shift occurs in the first 6-10 hours after launch. Postflight return is rapid, but a decrement persists. See page 59 herein.
447	Causative Agents During SMS	Dr. W. E. Thornton	---	---	Was incorporated into DSO 453 and flown under that designation.
448	Echographic Evaluation of Cardiovascular Deconditioning	Dr. M. W. Bungo	---	N/A	Resubmitted as a Form 100 Experiment (American Flight Echo).
449	Preflight and Postflight Parallel Swing Tests	Drs. D. E. Parker and M. Reschke	STS-8, 41B, and 51D	Complete; 5 of 6 requested subjects obtained (including those obtained as part of DSO 433).	Findings support the Otolith Tilt-Translation Reinterpretation Hypothesis and provide the basis for proposing a Preflight Adaptation Trainer (PAT). See page 145 in this report.
450	Salivary Cortisol During Acute Phases of Spaceflight	Dr. N. Cintron	STS-41G and 51L	Active; 1 of 6 requested subjects has been obtained.	Saliva collection is a viable tool for measurement of inflight cortisol levels. See page 31 in this report.

*As part of DSO 456.

MEDICAL DSOs LISTED BY NUMBER AND TITLE (Continued)

DSO	TITLE	INVESTIGATOR(S)	FLIGHT HISTORY	COMPLETION STATUS	SUMMARY OF RESULTS
451	Eye-Hand Coordination During SMS	Drs. W. E. Thornton and T. P. Moore	STS-51D*, 51B, 51J, and 61C	On hold; 5 of 10 requested subjects have been obtained.	No changes are apparent due to zero-G alone; data during SMS are under analysis. See page 164 in this report.
452	Leg Volume Changes	Drs. T. P. Moore and W. E. Thornton	---	On hold	---
453	Combined Blood Investigations	Drs. W. E. Thornton, C. Leach-Huntoon, H. Schneider, N. Cintrol, and Mr. R. Landry	STS-51B and 51F	Complete; 6 of 8 requested subjects have been obtained.	Some hypotheses about physiologic changes during spaceflight need additional study; new evidence indicates additional factors should be studied. See page 7 herein.
454	Clinical Characterization of SMS	Drs. W. E. Thornton and J. Vanderploeg	See DSO 455	See DSO 455	Redesignated DSO 455 before flight. See DSO 455 results.
455	Clinical Characterization of SMS	Drs. W. E. Thornton and J. Vanderploeg	STS-51D*, 51G, 51I, 51J, 61B, 61C, and 51L	Active; 7 of 12 requested subjects have been obtained.	Lack of bowel sounds may be a reliable indicator of SMS. Other data are being analyzed (pupillary size, skin color, etc.). See page 159 of this report.
456	Medical Tests and Measurements for the STS-51D Payload Specialist	Drs. Vanderploeg, Pool, Cintron, Charles, Inners, Reschke, Parker, Thornton, and Moore	STS-51D	Complete; 1 subject was obtained as requested.	This was a combination of many studies, including all or parts of DSOs 439, 441, 446, 449, 451, 455, 458, and 460. See results of individual studies.
457	Salivary Pharmacokinetics of Scop-Dex	Drs. N. Cintron and L. Putcha	STS-61B and 61C	Active; 3 of 6 requested subjects have been obtained.	There are apparent changes in the distribution of Scopolamine; a Dextroamphetamine assay is underway. See page 25 herein.
458	Salivary Acetaminophen Pharmacokinetics	Drs. N. Cintron and L. Putcha	STS-51D*, 51I, 61B, and 61C	Active; 5 of 6 requested subjects have been obtained.	A significant change has been noted in the disposition of acetaminophen taken inflight, in both drug concentration and time course. See page 19 of this report.

*As part of DSO 456.

MEDICAL DSOs LISTED BY NUMBER AND TITLE (Continued)

DSO	TITLE	INVESTIGATOR(S)	FLIGHT HISTORY	COMPLETION STATUS	SUMMARY OF RESULTS
459	Otolith Tilt-Translation Reinterpretation	Drs. M. Reschke and D. E. Parker	STS-61C and 51L	Active; 2 of 8 requested subjects have been obtained.	Pitch motion immediately after reentry was perceived as translation. Ocular counterrolling was observed inflight, but of a lower magnitude than preflight. These data will be of great help in designing a Preflight Adaptation Trainer (PAT). Due to late change in landing site, the most critical data (early postflight measurements) were not obtained. Subjective accounts of sensory perceptions were elicited in interviews. See pages 125 and 141 of this report.
460	Changes in Total Body Water During Spaceflight	Drs. C. S. Leach, L. D. Inners, and J. B. Charles	STS-51D* and 61C	Active; 3 of 5 requested subjects have been obtained.	Total body water decreases about 3% by day 2 of exposure to zero-G, then remains stable. See page 49 of this report.
461	Leg Plethysmography	Drs. T. P. Moore and W. E. Thornton	STS-51B, 51D*, and 51J (as DSO 446); 61B and 61C (as DSO 461)	Complete; 9 of 8 requested subjects were obtained (including those obtained as part of DSO 446).	There is typically a 1 liter volume change in each leg, largely due to shifts in body fluids. The shift occurs in the first 6-10 hours after launch. Postflight return is rapid, but a decrement persists. See page 59 herein.
462	Noninvasive Estimation of Central Venous Pressure	Drs. J. B. Charles and M. W. Bungo	STS-61C	Active; 1 subject has been obtained.	The technique is viable and produced good results. CVP decreased over the first three flight days, then remained at a constant value. See page 69 in this report.
463	Inflight Treadmill Stress Test	Drs. M. W. Bungo and J. B. Charles	STS-61C	Complete; 1 subject was obtained as requested.	No increase in ectopic activity was seen in this crewmember in contrast to the increase in dysrythmias seen during EVAs on previous STS Flights. See page 67 in this report.

*As part of DSO 456.

MEDICAL DSOs LISTED BY NUMBER AND TITLE (Concluded)

DSO	TITLE	INVESTIGATOR(S)	FLIGHT HISTORY	COMPLETION STATUS	SUMMARY OF RESULTS
464	Inflight Assessment of Renal Stone Risk Factor	Dr. N. Cintron	STS-61C	Active; 1 subject has been obtained.	Urine volume did not appear changed from preflight. A trend to increased excretion of calcium, phosphate, magnesium, and uric acid was present. See page 13 in this report.
465	Preflight and Postflight Echocardiography	Drs. J. B. Charles and M. W. Bungo	STS-61C	0 of 12 requested subjects was obtained. Will be supplanted by DSO 466.	Due to a last-minute change of landing site, no postflight data were collected. DSO 466 will replace 465 when flights resume.
466	Variations in Supine and Standing Heart Rate, Blood Pressure, and Cardiac Size as a Function of Space Flight Duration and Time Postflight	Drs. J. B. Charles and M. W. Bungo	Awaiting flight assignment	66 subjects from flights of varying durations have been requested.	TBD

MATRIX 2

MEDICAL DSOs - FLIGHT ASSIGNMENTS & SUBJECT COUNTS   Prepared by SBRI Flight Projects/MAB   2/27/87

DSO	SHORT TITLE	SUBJECTS APPROVED vs OBTAINED FOR EACH SHUTTLE FLIGHT																									TOT REQ vs OBT
		STS 1	STS 2	STS 3	STS 4	STS 5	STS 6	STS 7	STS 8	STS 9	STS 41B	STS 41C	STS 41D	STS 41G	STS 51A	STS 51C	STS 51D	STS 51B	STS 51G	STS 51F	STS 51I	STS 51J	STS 61A	STS 61B	STS 61C	STS 51L	
401	Predictive Tests	2 2	2 2	2 2	2 2	4 4	4 4	4 4	4 4	5 5	5 5	5 5	6 6	4 4	3 3	2 2	4 4	STANDARD OPERATING PROCEDURE ------------------									58 58 C
402	Fluid Loading	2 2	2 2	2 2	2 2	4 4	4 4	5 5	5 5	4 4	5 5	5 5	6 6	STANDARD OPERATING PROCEDURE ----------------------------------													46 46 C
403	Head & Eye Motion					1 1	1 1	1 1	2 2																		5 5 c
404	Head & Eye Tracking					? 2	4 4	? 5	5 5																		? 16 c
405	Acceleration Detection					? 0		? 0	0 2																		? 2 C
406	Kinesthetic Ability					? 0		? 1	? ?																		? 3-4C
407	Body Fluid Shifts						? 0	? 2	? 5																		? 7 C
408	Near Vision Acuity					4 4	4 4	5 5	5 5		2 0	5 5	2 2	4 2		5 5											36 32 C
409	Microbial Screening						1 1	1 1	1 1		1 1																4 4 C
410	Audiometry						4 4	? 4	5 5																		? 13 C
411	Mass Measurement								? 1																		? 1 C
412	Treadmill Operation							? 2	? ?																		? 2 C
413	Cell Attachment							1 1																			1 1 C
414	Ophthalmoscopy							2 2	? 2																		? 4 C

MEDICAL DSOs - FLIGHT ASSIGNMENTS & SUBJECT COUNTS (Continued) Prepared by SBRI Flight Projects/MAB 2/27/87

DSO	SHORT TITLE	SUBJECTS APPROVED vs OBTAINED FOR EACH SHUTTLE FLIGHT																									TOT REQ vs OBT
		STS 1	STS 2	STS 3	STS 4	STS 5	STS 6	STS 7	STS 8	STS 9	STS 41B	STS 41C	STS 41D	STS 41G	STS 51A	STS 51C	STS 51D	STS 51B	STS 51G	STS 51F	STS 51I	STS 51J	STS 61A	STS 61B	STS 61C	STS 51L	
415	Tissue Tonometry							? 1	? ?																		? 5 C
416	Ambulatory Monitoring							1 1	1 1																		2 2 C
417	SMS Countermeasures							? 0	1 1																		1 1 C
418	Eye-Hand Coordination								5 5																		5 5 C
419	Flavor Perception	DISAPPROVED ----------																									N/A
420	Taste Acuity in 0-G	DISAPPROVED ----------																									N/A
421	Animal Enclosure Module								1 1																		1 1 C
422	Anatomical Observation								5 5																		5 5 C
423	Inflight Fluid Changes								1 1																		1 1 C
424	Evoked Potentials								4 4																		4 4 C
425	Intraocular Pressure								1 1																		1 1 C
426	Denitrogenation	WITHDRAWN ----------																									N/A
427	Soft Contact Lens Test								1 1																		1 1 C
428	Unassigned																										N/A
429	Unassigned																										N/A
430	Unassigned																										N/A
431	Unassigned																										N/A

MEDICAL DSOs - FLIGHT ASSIGNMENTS & SUBJECT COUNTS (Continued) Prepared by SBRI Flight Projects/MAB 2/27/87

DSO	SHORT TITLE	SUBJECTS APPROVED vs OBTAINED FOR EACH SHUTTLE FLIGHT																									TOT REQ vs OBT
		STS 1	STS 2	STS 3	STS 4	STS 5	STS 6	STS 7	STS 8	STS 9	STS 41B	STS 41C	STS 41D	STS 41G	STS 51A	STS 51C	STS 51D	STS 51B	STS 51G	STS 51F	STS 51I	STS 51J	STS 61A	STS 61B	STS 61C	STS 51L	
432	Cell Attachment								1 1																		1 1 C
433/ 449	Parallel Swing Tests								1 1		2 2						3 2										6 5 C
434	Unassigned																										N/A
435	Unassigned																										N/A
436	Cardio Deconditioning	WITHDRAWN ----------																									N/A
437	Microbial Monitoring																	1 1									1 1 A
439	Action of Reglan												3 1	4 4		2 2	1 1	2 1									12 9 C
440	Visual Performance												2 2	4 3		5 5											11 10 C
441	BP Monitoring								1 1				1 1	2 0		1 1	2 2	2 2		2 2							9 9 H
442	Autogenic Feedback															1 1											1 1 C
443	Segmental Fluid Shift	ON HOLD ----------																									1 0 H
444	Unassigned																										N/A
445	Thoracic Impedance	ON HOLD ----------																									8 0 H
446/ 461	Leg Plethysmography																1 1	3 3				2 2		2 2	1 1		8 9 H
447	SMS Causative Agents	INCORPORATED INTO DSO 453 ----------																									N/A
448	Echocardiography	RESUBMITTED AS A FORM 100 EXPERIMENT ----------																									N/A
449	Parallel Swing Tests	SEE DSO 433 ----------																									6 5 C

MEDICAL DSOs - FLIGHT ASSIGNMENTS & SUBJECT COUNTS (Continued) Prepared by SBRI Flight Projects/MAB 2/27/87

DSO	SHORT TITLE	SUBJECTS APPROVED vs OBTAINED FOR EACH SHUTTLE FLIGHT																											TOT REQ vs OBT
		STS 1	STS 2	STS 3	STS 4	STS 5	STS 6	STS 7	STS 8	STS 9	STS 41B	STS 41C	STS 41D	STS 41G	STS 51A	STS 51C	STS 51D	STS 51B	STS 51G	STS 51F	STS 51I	STS 51J	STS 61A	STS 61B	STS 61C	STS 51L	
450	Salivary Cortisol													2 1												2 0	6 1 A
451	Eye-Hand Coordination																1 1	5 1				2 2			1 1		10 5 H
452	Leg Volume Changes	ON HOLD																									5 0 H
453	Blood Investigations																	4 2		4 4							8 6 C
454/ 455	Characterization of SMS																3 0		2 2		2 0			0 1	4 4	2 0	12 7 A
456	Tests & Measurements																1 1										1 1 C
457	Salivary Scop-Dex																							2 1	2 2		6 3 A
458	Salivary Acetaminophen																1 1				1 0			2 2	2 2		6 5 A
459	Otolith Tilt-Trans																								2 2	2 0	8 2 A
460	Total Body Water																1 0								3 3		5 3 A
461	Leg Plethysmography	SEE DSO 446																									8 9 H
462	Estimation of CVP																								1 1		1 1 H
463	Holter Monitoring																								1 1		1 1 H
464	Renal Stone Risk																								1 1		1 1 H
465/ 466	Pre & Postflight Echo																								1 0		66 0 A

NOTES:

1. Top numbers in the "Subjects Approved vs Obtained" columns represent the number of subjects approved by the Mission Integration Control Board (MICB) for each flight listed.
2. Bottom numbers in the "Subjects Approved vs Obtained" columns represent the number of subjects obtained on each of the flights listed.
3. Numbers in the "Total Requested vs Obtained" column represent the total number of subjects requested by the investigator(s) (top number) versus the number obtained to date (bottom number). The MICB attempts to schedule a DSO on an appropriate series of flights until the desired number of subjects is obtained.
4. Letters in the "Total Requested vs Obtained" column indicate the status of the DSO:
   - C = Complete
   - A = Active
   - H = On hold. Data is to be reviewed before the DSO is scheduled for reflight.
5. A question mark in a column indicates that the number is unknown or was not specified.
6. The protocols used in DSOs 401 and 402 have been adopted as Standard Operating Procedure to be used by Shuttle flight crews.
7. DSO 437 is to be flown on all flights on which animals will be exposed to cabin air.

MATRIX 3

DSO Investigators Prepared 2/19/87 by SBRI Flight Projects/MAB

INVESTIGATOR	ORG CODE	DSO NUMBER	SHORT TITLE OF DSO
Dr. M. W. Bungo	SD5	402	Cardiovascular Deconditioning Countermeasures
		462	Estimation of Central Venous Pressure
		463	Inflight Treadmill Stress Test
		465	Pre- and Postflight Echocardiography
Dr. J. B. Charles	SD5	460*	Total Body Water
		462	Estimation of Central Venous Pressure
		463	Inflight Treadmill Stress Test
		465	Pre- and Postflight Echocardiography
Dr. N. Cintron	SD4	450	Salivary Cortisol During Spaceflight
		453	Combined Blood Investigations
		457	Salivary Pharmacokinetics of Scop-Dex
		458*	Salivary Acetaminophen Pharmacokinetics
		464	Inflight Assessment of Renal Stone Risk Factor
Dr. P. S. Cowings	ARC	442	Autogenic Feedback Training (AFT)
Lt. Col. L. V. Genco	USAF	440	Crew Visual Performance Testing
Dr. A. Ginsberg	USAF	408	Near Vision Acuity (Contrast Sensitivity)
Dr. J. L. Homick	SD	401	Predictive Tests and Countermeasures for SMS
Dr. L. D. Inners	SD4	460*	Total Body Water
Dr. P. C. Johnson	SD	402	Cardiovascular Deconditioning Countermeasures
Dr. C. S. Leach	AC	423	Study of Inflight Fluid Changes
		453	Combined Blood Investigations
		460*	Total Body Water
Dr. T. P. Moore	SD5	441*	Blood Pressure Monitoring During Re-entry
		446/461*	Leg Plethysmography
		451*	Eye-Hand Coordination During SMS
		456	Medical Tests and Measurements (51D P/S)
Dr. D. R. Morrison	SD3	413	Cell Attachment in Microgravity
		432	Carry-on Incubator/Cell Attachment in Micro-G
Dr. D. E. Parker	SD5	433/449*	Pre- and Postflight Parallel Swing
		459	Otolith Tilt-Translation Reinterpretation
Dr. D. L. Pierson	SD4	409	Microbial Screening
		437	Microbial Monitoring
Dr. S. L. Pool	SD	425	Intraocular Pressure

INVESTIGATOR	ORG CODE	DSO NUMBER	SHORT TITLE OF DSO
Dr. L. Putcha	SD4	457	Salivary Pharmacokinetics of Scop-Dex
		458*	Salivary Acetaminophen Pharmacokinetics
Dr. M. Reschke	SD5	433/449*	Pre- and Postflight Parallel Swing
		459	Otolith Tilt-Translation Reinterpretation
Dr. H. Schneider	SD4	453	Combined Blood Investigations
Dr. E. L. Shulman	CB	414	Ophthalmoscopy
Dr. M. C. Smith		421	Animal Enclosure Module Inflight Test
Dr. W.E. Thornton	CB	403	Head and Eye Motion During Re-entry
		404	On-Orbit Head and Eye Tracking Tasks
		405	Acceleration Detection Sensitivity
		406	Kinesthetic Ability
		407	Photographic Documentation of Body Fluid Shift
		410	Audiometry
		411	Simple Mass Measurement
		412	Treadmill Operation
		415	Tissue Pressure Tonometry
		416	Ambulatory Monitoring
		417	Inflight Countermeasures for SAS
		418	Eye-Hand Coordination
		422	Anatomical Observation
		423	Study of Inflight Fluid Changes
		424	Evoked Potentials
		427	Soft Contact Lens Application
		439*	Documentation of the Action of Metoclopramide
		441*	Blood Pressure Monitoring During Re-entry
		446/461*	Leg Plethysmography
		451*	Eye-Hand Coordination During SMS
		453	Combined Blood Investigations
		454/455	Clinical Characterization of SMS
		456	Medical Tests and Measurements (51D P/S)
Dr. J.M. Vanderploeg	SB	408	Near Vision Acuity (Contrast Sensitivity)
		454/455	Clinical Characterization of SMS
		456	Medical Tests and Measurements (51D P/S)

* Included as part of DSO 456.
AC, CB, SB, SD, SD3, SD4, and SD5 are NASA JSC mail codes.
ARC - NASA Ames Research Center.
USAF - United States Air Force.

MATRIX 4

MEDICAL DSOs LISTED BY DISCIPLINE   Prepared by SBRI Flight Projects/MAB   2/19/87   Page 1 of 2

DISCIPLINE	DSO	SHORT TITLE	INVESTIGATOR(S)
Biochemistry and Pharmacology	447*	Causative Agents During SMS	
	450	Salivary Cortisol During Spaceflight	Dr. N. Cintron
	453	Combined Blood Investigations	Drs. C. S. Leach et al.
	456	Medical Tests and Measurements (51D P/S)	Drs. W. E. Thornton et al.
	457	Salivary Pharmacokinetics of Scop-Dex	Drs. N. Cintron and L. Putcha
	458	Salivary Acetaminophen Pharmacokinetics	Drs. N. Cintron and L. Putcha
	464	Inflight Assessment of Renal Stone Risk Factor	Drs. N. Cintron
Cardiovascular Effects and Fluid Shifts	402	Cardiovascular Deconditioning Countermeasures	Drs. M. W. Bungo and P. C. Johnson
	407	Photographic Documentation of Body Fluid Shift	Dr. W. E. Thornton
	412	Treadmill Operation	Treadmill Operation
	415	Tissue Pressure Tonometry	Dr. W. E. Thornton
	423	Study of Inflight Fluid Changes	Drs. W. E. Thornton and C. S. Leach
	436#	Monitoring of Cardiovascular Deconditioning	Dr. M. W. Bungo
	441	Blood Pressure Monitoring During Re-entry	Drs. W. E. Thornton and T. P. Moore
	443#	Segmental Fluid Shift	Dr. J. S. Logan, et al.
	445	Thoracic Impedence Measurements	Drs. T. P. Moore and W. E. Thornton
	446	Leg Plethysmography	Drs. T. P. Moore and W. E. Thornton
	448@	Echocardiographic Evaluation of Deconditioning	Drs. M. W. Bungo and J. B. Charles
	452#	Leg Volume Changes	Drs. T. P. Moore and W. E. Thornton
	456	Medical Tests and Measurements (51D P/S)	Drs. W. E. Thornton, et al.
	460	Changes in Total Body Water During Spaceflight	Drs. C. S. Leach, D. L. Inners, et al.
	461	Leg Plethysmography	Drs. T. P. Moore and W. E. Thornton
	462	Estimation of Central Venous Pressure	Drs. M. W. Bungo and J. B. Charles
	463	Inflight Treadmill Stress Test	Drs. M. W. Bungo and J. B. Charles
	465	Pre and Postflight Echocardiography	Drs. M. W. Bungo and J. B. Charles
	466	Variations in Supine & Standing ... Heart Size ...	Drs. M. W. Bungo and J. B. Charles
Equipment Testing and Experiment Verification	411	Simple Mass Measurement	Dr. W. E. Thornton
	421	Animal Enclosure Module Inflight Test	Dr. M. C. Smith
	426#	Denitrogenation Procedures Evaluation	Dr. J. M. Waligora and D. J. Horrigan
	442	Autogenic Feedback Training (AFT)	Dr. P. S. Cowings
Microbiology	409	Microbial Screening	Dr. D. L. Pierson
	413	Cell Attachment in Microgravity	Dr. D. R. Morrison
	432	Carry-on Incubator/Cell Attachment in Micro-G	Drs. D. R. Morrison and A. Cogoli
	437	Microbial Monitoring	Dr. D. L. Pierson

MEDICAL DSOs LISTED BY DISCIPLINE (Continued)

DISCIPLINE	DSO	SHORT TITLE	INVESTIGATOR(S)
Space Motion Sickness and Space Adaptation Studies	401	Predictive Tests and Countermeasures for SMS	Dr. J. L. Homick
	403	Head and Eye Motion During Re-entry	Dr. W. E. Thornton
	404	On-Orbit Head and Eye Tracking Tasks	Dr. W. E. Thornton
	405	Acceleration Detection Sensitivity	Dr. W. E. Thornton
	406	Kinesthetic Ability	Dr. W. E. Thornton
	410	Audiometry	Dr. W. E. Thornton
	414	Ophthalmoscopy	Dr. E. L. Shulman
	416	Ambulatory Monitoring	Dr. W. E. Thornton
	417	Inflight Countermeasures for SAS	Dr. W. E. Thornton
	418	Eye-Hand Coordination	Dr. W. E. Thornton
	419!	Food Flavor Perception in Zero Gravity	R. L. Sauer
	420!	Taste Acuity In Zero Gravity	R. L. Sauer
	422	Anatomical Observation	Dr. W. E. Thornton
	424	Evoked Potentials	Dr. W. E. Thornton
	425	Intraocular Pressure	Dr. S. L. Pool
	427	Soft Contact Lens Application Test	Drs. W. E. Thornton and L. R. Young
	433	Pre- and Postflight Parallel Swing Tests	Drs. D. E. Parker and M. L. Reschke
	439	Documentation of the Action of Metoclopramide	Dr. W. E. Thornton
	447*	Causative Agents During SMS	Dr. W. E. Thornton
	449	Pre- and Postflight Parallel Swing Tests	Drs. D. E. Parker and M. L. Reschke
	451	Eye-Hand Coordination During SMS	Drs. W. E. Thornton and T. P. Moore
	454/455	Clinical Characterization of SMS	Drs. W. E. Thornton and J. Vanderploeg
	456	Medical Tests and Measurements (51D P/S)	Drs. W. E. Thornton et al
	459	Otolith Tilt-Translation Reinterpretation	Drs. M. L. Reschke and D. E. Parker
Vision	408	Near Vision Acuity & Contrast Sensitivity	Drs. A. Ginsberg and J. M. Vanderploeg
	440	Crew Visual Performance Testing	Lt. Col. L. V. Genco and Dr. H. L. Task

LEGEND:

* Was incorporated into DSO 453 and flown under that designation

\# Withdrawn

@ Resubmitted as a Form 100 Experiment; flown as American Flight Echocardiograph (AFE)

! Disapproved

MATRIX 5

CURRENTLY ACTIVE MEDICAL DSO Prepared 02-20-87 by SBRI Flight Projects/MAB

DSO	TITLE	PRINCIPAL INVESTIGATOR(S)	STATUS
437	Microbial Monitoring	Dr. D. L. Pierson	To be flown when animals are on board
450	Salivary Cortisol During Acute Phases of Spaceflight	Dr. N. Cintron	5 additional subjects are needed to reach the approved total.
455	Clinical Characterization of SMS	Drs. W. E. Thornton and J. Vanderploeg	Need additional subjects with SMS (minimum of 6 more)
457	Salivary Pharmacokinetics of Scop-Dex	Drs. N. Cintron and L. Putcha.	3 additional subjects are needed to reach the approved total.
458	Salivary Acetaminophen Pharmacokinetics	Drs. N. Cintron and L. Putcha	1 additional subject is needed to reach the approved total.
459	Otolith Tilt-Translation Reinterpretation	Drs. M. Reschke and D. E. Parker	6 additional subjects are needed to reach the approved total.
460	Changes in Total Body Water During Spaceflight	Drs. C. Leach-Huntoon, L. D. Inners, and J. B. Charles	2 additional subjects are needed to reach the approved total.
462	Noninvasive Estimation of Central Venous Pressure	Drs. M. W. Bungo and J. B. Charles	Initially approved only for STS-61C; additional subjects have been requested.
464	Inflight Assessment of Renal Stone Risk Factor	Dr. N. Cintron	Initially approved only for STS-61C; additional subjects have been requested.
465/466	Pre and Postflight Echocardiography	Drs. M. W. Bungo and J. B. Charles	DSO 465 was approved for STS-61C and later supplanted by DSO 466. 66 subjects on missions of various durations are needed.

MATRIX 6

STS FLIGHT HISTORY

Prepared by SBRI Flight Projects/MAB 2/26/87

FLIGHT NUMBER	VEHICLE	LAUNCH DATE	DURATION (DAYS)	LANDING SITE	CREWMEMBERS	PAYLOADS	MED DSOs	COMMENTS
STS-1	Columbia	4-12-81	2.25	EAFB	John W. Young Robert L. Crippen	DFI	401 402	First Orbital Flight Test (OFT) of the Space Shuttle System.
STS-2	Columbia	11-12-81	2.25	EAFB	Joe H. Engle Richard H. Truly	DFI OSTA-1 ACIP	401 402	Second OFT; first test of Remote Manipulator System (RMS); mission cut to 2 days by fuel cell failure.
STS-3	Columbia	3-22-82	8.00	EAFB	Jack Lousma C. Gordon Fullerton	DFI OSS-1 ACIP GAS EEVT MLR PDP	401 402	Third OFT; student experiments; test of hardware for electrophoresis operations (EEVT); landing site changed to Northrop Strip (White Sands, NM) due to water on lakebed at Edwards AFB; landing delayed one day due to weather at the alternate landing site.
STS-4	Columbia	6-27-82	7.04	EAFB	Thomas K. Mattingly Henry Hartsfield	DFI MLR CFES GAS IECM NOSL ACIP	401 402	Fourth OFT; included a DOD payload; first flight of Continuous Flow Electrophoresis System (CFES).
STS-5	Columbia	11-11-82	5.08	EAFB	Vance D. Brand Robert Overmyer William Lenoir Joseph Allen	TELESAT-E SBS-C	401-406 408 (7 DSOs)	First operational flight; first deployment of satellites.
STS-6	Challenger	4-04-83	5.00	EAFB	Paul J. Weitz Karol J. Bobko Donald H. Peterson F. Story Musgrave	TDRS-A CFES MLR NOSL GAS	401-406 407-410 (8 DSOs)	First flight of Challenger; first Shuttle EVA (Peterson, Musgrave); TDRS failed to reach geosynchronous orbit due to IUS guidance failure.

STS FLIGHT HISTORY (Continued)

FLIGHT NUMBER	VEHICLE	LAUNCH DATE	DURATION (DAYS)	LANDING SITE	CREWMEMBERS	PAYLOADS	MED DSOs	COMMENTS
STS-7	Challenger	6-18-83	6.08	EAFB	Robert L. Crippen Frederick H. Hauck Sally K. Ride John M. Fabian Norman E. Thagard	TELESAT PALAPA B-1 SPAS-01 OSTA-2 CFES	401-410 412-417 (16 DSOs)	Physician crewman (Thagard) to study SMS; use of RMS to deploy and retrieve the Shuttle Pallet Satellite (SPAS-1); scheduled landing at KSC waved-off due to bad weather (changed to EAFB).
STS-8	Challenger	8-30-83	6.04	EAFB	Richard H. Truly Daniel C. Brandenstein Guion S. Bluford Dale A. Gardner William E. Thornton	INSAT 1-B PFTA	401-412 414-418 421-425 427 432-433 441 (26 DSOs)	First Shuttle night launch & landing; physician crewman (Thornton) made use of DSOs to continue inflight study of SMS.
STS-9	Columbia	11-28-83	10.32	EAFB	John W. Young Brewster H. Shaw Robert A. Parker Owen K. Garriott Byron Lichtenberg Ulf Merbold	Spacelab 1	401-402 409	Two-shift, 24 hr/day operations; astronomy, physics, materials sciences, and biomedical research (neurovestibular, cardiovascular, hematological, immunological, & psychological adaptation to space flight); first non-US crewmember (Merbold-Germany).
STS 41-B	Challenger	2-03-84	7.97	KSC	Vance D. Brand Robert L. Gibson Bruce McCandless II Robert L. Stewart Ronald E. McNair	SPAS-01A PALAPA B-2 WESTAR-VI	401-402 408 433	First test of MMU, first KSC landing; both satellites failed to reach geosynchronous orbit due to PAM failures.
STS 41-C	Challenger	4-06-84	6.99	EAFB	Robert L. Crippen Francis R. Scobee Terry J. Hart James D. van Hoften George D. Nelson	LDEF-1	401-402 408	Rendezvous, repair, and redeploy of Solar Max satellite; student experiment (bees); highest STS altitude to date (269 nautical miles).
STS 41-D	Discovery	8-30-84	6.04	EAFB	Henry W. Hartsfield Michael L. Coats Richard M. Mullane Stephen A. Hawley Judith A. Resnik Charles D. Walker	OAST-1 SBS-D TELSTAR 3C SYNCOM IV-1 CFES	401-402 408 439-441 (6 DSOs)	Evaluation of the deployable solar array (OAST-1); first "frisbee" type satellite deployment (SYNCOM); first commercial payload specialist (Charles Walker).

STS FLIGHT HISTORY (Continued)

FLIGHT NUMBER	VEHICLE	LAUNCH DATE	DURATION (DAYS)	LANDING SITE	CREWMEMBERS	PAYLOADS	MED DSOs	COMMENTS
STS 41-G	Challenger	10-05-84	8.23	KSC	Robert L. Crippen Jon A. McBride David D. Leestma Sally K. Ride Kathryn D. Sullivan Paul D. Scully-Power Marc Garneau	OSTA-3 LFC/ORS ERBS IMAX GAS (8)	401 408 439-441 450 (6 DSOs)	First American woman to perform an EVA (Sullivan); first seven person crew; first American orbital fuel transfer; first Canadian crewman (Garneau).
STS 51-A	Discovery	11-08-84	7.99	KSC	Frederick H. Hauck David M. Walker Dale A. Gardner Joseph P. Allen Anna L. Fisher	MSL-1 SYNCOM IV-2 TELESAT	401	2 EVAs for retrieval of PALAPA-B-2 and WESTAR VI satellites from STS-11
STS 51-C	Discovery	1-24-85	3.06	KSC	Thomas K. Mattingly Loren J. Shriver Ellison S. Onizuka James F. Buchli Gary E. Payton	DOD	401 408 (6 DSOs)	First dedicated DOD mission; test of hardware for SL-3 Autogenic Feedback Experiment (DSO 442).
STS 51-D	Discovery	4-12-85	7.00	KSC	Karol J. Bobko Donald E. Williams M. Rhea Seddon Jeffrey A. Hoffman S. David Griggs Charles D. Walker E. J. "Jake" Garn	SYNCOM IV-3 TELESAT-I CFES	401 456	SYNCOM failed to activate after deployment; unscheduled EVA to attach "fly swatters" to RMS for attempt to trip the activation switch; American Flight Echocardiograph (AFE) provided first American heart images inflight; U.S. Senator as payload specialist.
STS 51-B	Challenger	4-29-85	6.96	EAFB	Robert F. Overmyer Frederick D. Gregory Don L. Lind Normal E. Thagard William E. Thornton Lodewijk van den Berg Taylor G. Wang	Spacelab 3 NUSAT GLOMR	437 451 439 453 441 462 (6 DSOs)	Crystal growth and materials science experiments; Auroral photography; test of Research Animal Holding Facility (failure caused contamination); test of Autogenic Feedback Training for effectiveness in combatting SMS.

STS FLIGHT HISTORY (Continued)

FLIGHT NUMBER	VEHICLE	LAUNCH DATE	DURATION (DAYS)	LANDING SITE	CREWMEMBERS	PAYLOADS	MED DSOs	COMMENTS
STS 51-G	Discovery	6-17-85	7.07	EAFB	Daniel C. Brandenstein John O. Creighton Shannon W. Lucid John M. Fabian Steven R. Nagel Patrick Baudry Sultan S. A. Al-Saud	ARABSAT-A TELSTAR-3D SPARTAN 101/MPESS MORELOS-A	455	The French Echocardiograph Experiment (FEE) and French Posture Experiment (FPE) provided data on physiological adaptation to Space Flight.
STS 51-F	Challenger	7-29-85	7.95	EAFB	C. Gordon Fullerton Roy D. Bridges F. Story Musgrave Anthony W. England Karl G. Henize Loren W. Acton John-David Bartoe	Spacelab-2	441 453	Around-the-clock astronomy studies, including extensive solar observation; blood collection for bitamin D metabolites; plant growth.
STS 51-I	Discovery	8-27-85	7.10	EAFB	Joe H. Engle Richard O. Covey James Van Hoften John M. Lounge William F. Fisher	SYNCOM IV-4 ASC-1 AUSSAT-1 MSL-2 CFES	455 458	Rendezvous with failed SYNCOM from mission 51-D; EVA for capture and repair; redeploy.
STS 51-J	Atlantis	10-03-85	4.07	EAFB	Karol J. Bobko Ronald J. Grabe Robert C. Stewart David C. Hilmers William A. Pailes	DOD	451 461	Second dedicated DOD mission; first flight of Atlantis.
STS 61-A	Challenger	10-30-85	7.00	EAFB	Henry W. Hartsfield Steven R. Nagel Bonnie J. Dunbar Guion S. Bluford James F. Buckli Reinhard Furrer Wubbo Ockels Ernst Messerschmid	Spacelab D-1 GLOMR	---	First 8 person crew; first foreign dedicated Spacelab (West Germany); life sciences experiments (neurovestibular, cardiovascular, immunological) and materials sciences.

STS FLIGHT HISTORY (Continued)

FLIGHT NUMBER	VEHICLE	LAUNCH DATE	DURATION (DAYS)	LANDING SITE	CREWMEMBERS	PAYLOADS	MED DSOs	COMMENTS
STS 61-B	Atlantis	11-26-85	6.87	EAFB	Brewster H. Shaw Bryan D. O'Connor Mary L. Cleave Sherwood C. Spring Jerry L. Ross Charles D. Walker Rodolfo Neri	MORELOS-B SATCOM Ku-2 AUSSAT-1 EASE/ACCESS CFES IMAX	455 457 458 461	2 EVAs for assembly of EASE and ACCESS truss structures to evaluate Space Station construction techniques.
STS 61-C	Columbia	1-12-86	5.09	EAFB	Robert L. Gibson Charles F. Bolden Franklin Chang-Diaz George D. Nelson Steven A. Hawley Bill Nelson Robert J. Cenker	SATCOM Ku-1 MSL-2 GAS Bridge	451 455 457-465 (11 DSOs)	U.S. Congressman payload specialist performed 10 biomedical DSOs; landing at KSC delayed two days and waved-off due to weather.
STS 51-L	Challenger	1-28-86	---	---	Francis R. Scobee Michael J. Smith Judith A. Resnik Ellison S. Onizuka Ronald E. McNair Gregory Jarvis Sharon C. McAuliffe	TDRS-B SPARTAN- Halley	450 455 459	Explosion claims crew and orbiter at 73 seconds into the flight.

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Space
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Johnson Space Center
Houston, Texas 77058

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MEDICAL SCIENCES DIVISION

Lyndon B. Johnson Space Center
Houston, Texas 77058