NAMI-974

THE INVERSION ILLUSION IN PARABOLIC FLIGHT: ITS PROBABLE DEPENDENCE ON OTOLITH FUNCTION

Ashton Graybiel and Robert S. Kellogg

NASA JOINT REPORT

DEPARTMENT OF THE NAVY
U.S. NAVAL AEROSPACE MEDICAL INSTITUTE

UNITED STATES NAVAL AEROSPACE MEDICAL INSTITUTE
UNITED STATES AIR FORCE
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

July 1966

Distribution of this document is unlimited.

THE INVERSION ILLUSION IN PARABOLIC FLIGHT:

ITS PROBABLE DEPENDENCE ON OTOLITH FUNCTION*

Ashton Graybiel and Robert S. Kellogg

Bureau of Medicine and Surgery
MR005.04-0021.134

NASA Order R-93

Released by

Captain H. C. Hunley, MC USN
Commanding Officer

20 July 1966

*This research was conducted under the sponsorship of the Office of Advanced Research and Technology, National Aeronautics and Space Administration.

U. S. NAVAL AEROSPACE MEDICAL INSTITUTE
U. S. NAVAL AVIATION MEDICAL CENTER
PENSACOLA, FLORIDA

SUMMARY PAGE

THE PROBLEM

The two-fold purpose of this report is to describe brief experiments carried out in parabolic flight and to discuss the findings in the light of their possible implications for space flight. Observations were made on normal subjects and deaf persons with bilateral labyrinthine defects (L-D subjects) under three different conditions in parabolic flight: 1) free-floating, 2) restrained in a Fiberglas mold, and 3) "standing" on the overhead during a modified parabola generating about -0.05 G unit.

FINDINGS

There were interindividual differences in the reactions among the normal but not among the L-D subjects. Some normal but none of the L-D subjects experienced a reversal of their personal orientation with regard to up-down under all three conditions. This "reversal" was considered to have its genesis in the vestibular organs, probably the otolith apparatus. Our findings are in accord with Russian reports describing feelings of inversion among cosmonauts in orbital flight. Attention is called to the necessity of distinguishing between information furnished by touch-pressure, kinesthesis, and stere-agnosis under ordinary conditions and agravic touch-pressure, agravic kinesthesis, and agravic steragnosis.

INTRODUCTION

The two-fold purpose of this report is to describe three brief experiments carried out in parabolic flight and to discuss the findings in the light of their possible implications for space flight. The stimulus to initiate these investigations was provided by Lieutenant B. C. Neider, Jr., USN, who experienced a curious illusion while free-floating during parabolic maneuvers. His observations were made, incidentally, during a concurrent experiment in which normal subjects and persons with bilateral labyrinthine defects (L-D subjects) were being tested. Although there was only a limited opportunity to expand the scope of the primary undertaking , it seemed worthwhile to make some comparative observations on the perception of the upright in the normal and L-D subjects.

PROCEDURE

SUBJECTS AND AIRCRAFT

Four L-D and seven normal subjects participated. All were in excellent general health and perforce had gone through the medical and indoctrinational tests qualifying them for zero G flights.

The significant clinical findings in the L-D subjects are summarized in Table I. The normal subjects ranged in age from 19 to 38 years. None had any symptoms referable to the organs of the inner ear. All had normal hearing and normal semicircular canal function as determined by routine tests. Ocular counterrolling, a test of otolith function, was carried out in four of the seven and the findings were normal.

Although all of the subjects had experienced the parabolic maneuver, only three were highly sophisticated, and, for convenience, the other eight are referred to as "unsophisticated."

Both the KC-135 (Boeing 707) and C-131B (Convair) planes were used. The flight profile for the KC-135, described elsewhere in detail (1), consisted essentially of a ballistic trajectory with a weightless period of about twenty-five to thirty seconds preceded and followed by a pull-up, quickly generating about 2.0 G. In the C-131B the weightless period was twelve to sixteen seconds, and the G load during pull-ups was about 2.5 G (Figure 1). It is essential to emphasize that the entire parabolic maneuver is measured in seconds and that 20 maneuvers might be flown on a single sortie. Moreover, accelerometer readings at the center of gravity of the aircraft varied by at least 0.02 G even under good weather conditions. Fore and aft of the center of gravity the G load was slightly less and greater, respectively, but the amount was "insignificant." When secured to the aircraft the subject experienced not only the variations in G load but also very small changes in angular velocity. While "free-floating" in the padded after-portion of the aircraft, the subject was weightless except for the inertial forces generated by bodily movements (2).

Table I

Clinical Findings in Four Deaf Subjects with Bilateral Labyrinthine Defects

		Auricular Defects		Hearing*		Nystagmus Response Caloric Test		C-R Index▲ Max. Tilt‡	
Subj.	Age	Etiology	Age Onset	R	L	R	L	50°	75°
JO	34	Meningitis	$7\frac{1}{2}$	Nil	Nil	Nil	Nil	126	176
HA	29	Meningitis	13	Nil	Nil	Nil	Nil	47	53
PE	33	Meningitis	12	Nil	Nil	Nil	Nil	21	30
MY	25	Meningitis	8	Nil	Nil	Nil	Positive#	63	82

*Response to 160 db white noise.

#Irrigation 40 sec. water temp. 7.9°C.

▲One-half the sum of maximum roll right and left (min. of arc).

‡Angular displacement of body from vertical in frontal plane.

ZERO-GRAVITY FLIGHT TRAJECTORY

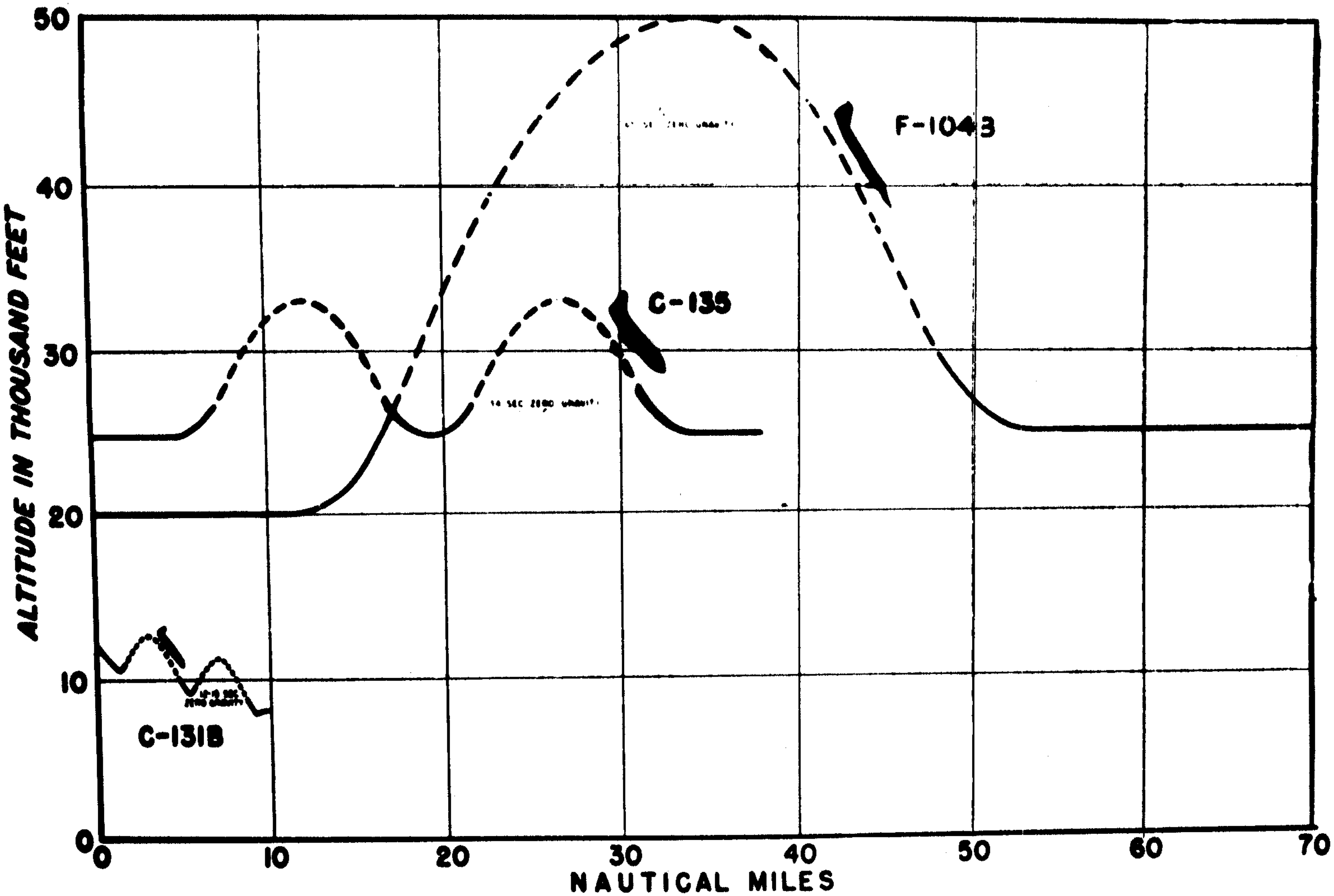

Figure 1

Flight Profiles of Zero G Maneuvers

EXPERIMENTS

1. Free - Floating

The initial observations were made by Lieutenant Neider, an aviator serving as one of the normal subjects in the primary experiment but with no previous experience in zero G flights. In an "off-duty" period, while free-floating in the after-portion of the aircraft he experienced "a sudden reversal of up and down." The illusion lasted only a matter of seconds and had two related aspects, a bodily feeling of sudden reversal of the upright and a belief that the plane was flying upside down. He determined that at least two additional factors seemed to be essential for the perception of the illusion. The more important of the two was a head-lower-than-foot position with reference to the cabin; indeed, the more closely he assumed the inverted position the more readily he experienced the illusion. The second condition was the necessity to face the forward end of the cabin, the long axis of which had the "characteristics of a tunnel." He stated that these were the only occasions during which he had experienced disorientation in flight.

Three normal subjects, of whom two were sophisticated, were instructed to assume the position Neider had found most advantageous for experiencing the illusion. Upon entering weightlessness, the men, through their own efforts, assumed a head-down position with respect to the aircraft and faced the long axis of the cabin. This was usually accomplished within a period of two to six seconds. Although all reported that "down" was where their feet were, only the naive subject thought that the plane was upside down. The four L-D subjects, who experienced a very brief period of free-floating in the "Neider position," in connection with the negative G experiment did not experience an illusion.

Comment. - Simons and Gardner (3) published verbatim accounts of subjects' perceptions while free-floating in darkness with a single light source. One subject stated, "As soon as my feet were placed on the ceiling I regained my orientation with the ceiling as down" (3, p 12). Another subject reported, "Now I have the sensation of moving forward, I am against (momentarily touched) the floor, now I feel upside down (free-floating)" (3, p 55). Several variants of these perceptions were reported also. Captain Simons (personal communication) has stated that, although it was a fairly common experience for subjects suddenly to feel reoriented with regard to up-down, he did not recall that they expressed the belief that the plane had inverted and added, "Maybe they did not get that far in their thinking."

Kas'yan, Kolosov, Lebedev, and Yurov (4) have reviewed the experiences of Russian cosmonauts in parabolic flight and have written as follows: "In the case of visual control of the position of the aircraft under conditions of weightlessness no instances of spatial disorientation were observed in the cosmonauts. When eyes were closed illusory sensations of the position of the aircraft and body in space were observed. None of them was able to determine the actual nature of evolutions effected by the aircraft." No further details were given.

Neider's emphasis on the head-down orientation with reference to the cabin as a contributing factor is at least in line with Simon's (5) concept of "foot-down orientation"; that is to say, in weightlessness, one tends to regard where the feet are as "down." Although one might be inclined to ascribe the illusion to negative G, this was almost ruled out by the fact that the subjects were free-floating. The possibility that a thrust by hand or foot against the fuselage generated an adequate stimulus was unlikely in view of the elapsed time of at least two seconds required to get into position. Many more observations under carefully controlled conditions will be required to determine both susceptibility to and the precise role of the several factors contributing to the illusion.

II. Negative G

In this experiment the subject's task was to "stand" on the overhead of the aircraft while exposed to small negative G loadings in modified parabolic maneuvers (Figure 2). It was not part of the primary experiment, and we are greatly obliged to Captain E. J. Hatzenbuchler, USAF, through whose efforts this was made possible.

All of the L-D and five of the normal subjects participated; three of the latter were sophisticated. In the C-131B aircraft the overhead walkway was aft of the center of gravity. The parabolic trajectory was altered in order to generate small negative G loadings lasting a matter of seconds. It is important to point out that during these brief periods, the gravitoinertial upright was directed toward the floor approximately 180 degrees from the visual upright.

The subjects were shown the procedure, and in some instances a familiarization trial was required. The procedure consisted of lying supine and, as the transition through the weightless period occurred, rising to a standing position in a matter of two to three seconds. The period during which the subject's feet were on the overhead was less than the total available time but probably included the occurrence of the peak load in each instance. Table II summarizes the accelerometer readings obtained during the exposure of the L-D subjects; the normal subjects were exposed to at least two parabolic maneuvers under similar negative G loadings.

Results.- Each of the L-D subjects expressed himself differently, but all felt upside down with reference to the cabin. JO: "Feet upside down very definitely (with reference to the cabin). No feeling of being upright. The pressure on my feet was too little to cause any postural feeling." HA felt he was upside down: "Everything completely normal; i.e., I felt I was doing exactly what I was doing. Negative G only was not enough to give sensation of normal weight." PE: "Both times it was difficult to say whether I was upside down or the plane was. If not for the standard (visual) cues (seats, passages, etc.), I couldn't tell. If my eyes were closed I would feel upright." MY: "For the first few seconds (about five seconds) I felt that I was not upside down except for seeing that I was - after about five seconds, I began to feel blood coming to my head, and then I began to feel that I was upside down."

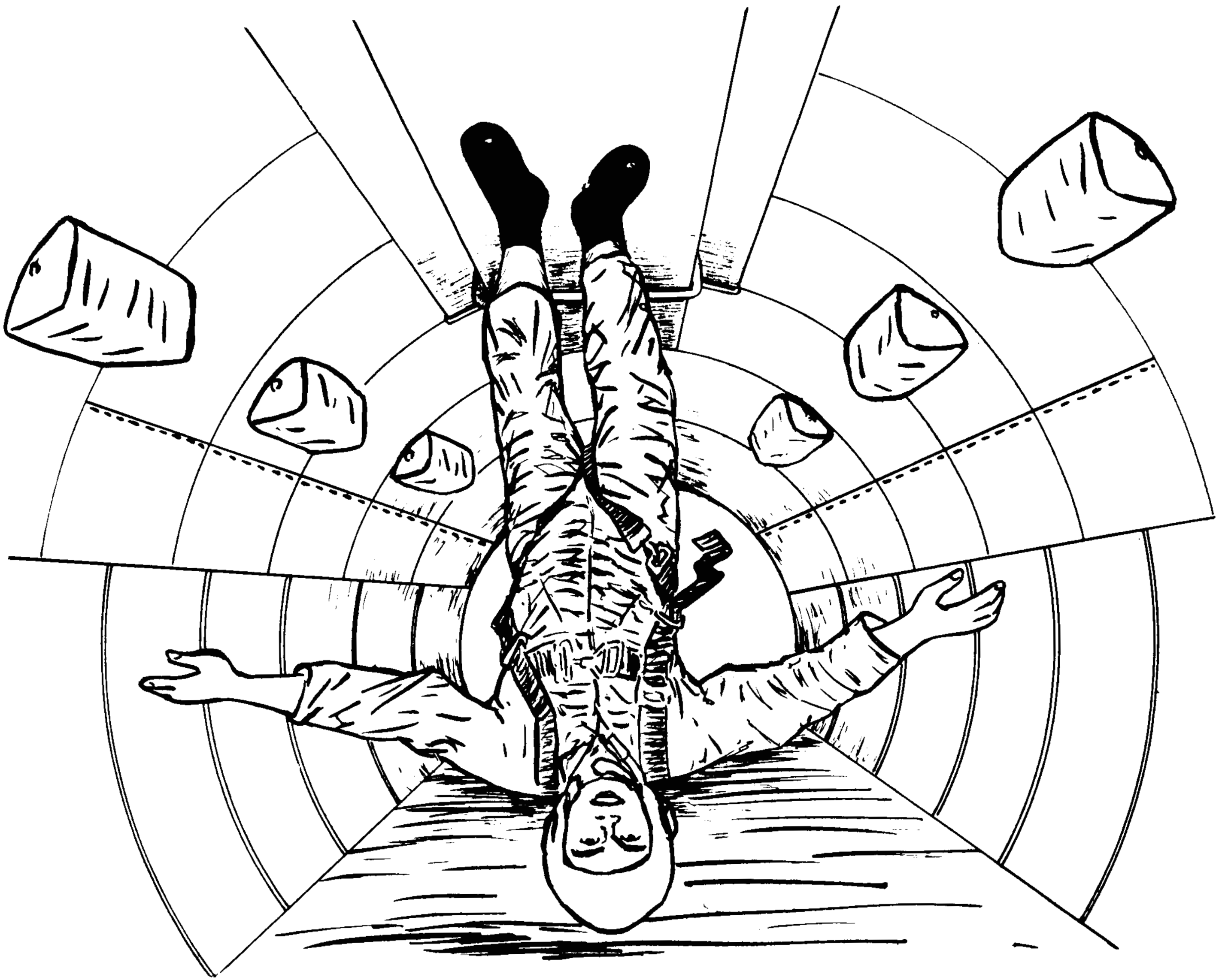

Figure 2

Subject Standing on Overhead of C-131B Aircraft in Modified Parabolic Maneuver

Table II

LEVEL AND DURATION OF NEGATIVE G TO WHICH FOUR LABYRINTHINE-DEFECTIVE SUBJECTS WERE EXPOSED IN MODIFIED PARABOLIC FLIGHT

SUB.	Trial	TOTAL PERIOD		PEAK PERIOD	
		DUR.(SEC)	G LEVEL	DUR.(SEC)	G LEVEL
JO	1	6.5	-0.075	0.5	-0.10
	2	6.5	-0.048	0.25	-0.072
	3	8.0	-0.049	0.5	-0.09
HA	1	6.5	-0.04	0.05	-0.058
	2	8.5	-0.048	2.8	-0.058
PE	1	9.1	-0.049	0.5	-0.09
	2	7.5	-0.048	0.25	-0.07
MY	1	7.0	-0.048	0.1	-0.06
	2	7.5	-0.049	1.5	-0.06

Two of three sophisticated normal subjects regarded themselves simply as being upside down in a right-side-up aircraft. In other words, their experience was similar to that of the L-D subjects. The remaining three subjects, one of whom was sophisticated, reported that they regarded themselves as right side up in an aircraft flying in an inverted position.

Comment. - The analogy to "contact" flight may be pertinent. The tyro usually regards the aircraft rather than the Earth as the fixed frame of reference but quickly learns to correct the error. He comes to regard conflicting visual and gravitational cues as normal inputs under the circumstances although requiring special interpretation. The L-D and unsophisticated subjects behaved differently: The former described the circumstances correctly but accepted the apparent miracle of "standing" on the overhead; the normal subjects (and one sophisticated subject) correctly interpreted the gravitoinertial up-down and regarded the aircraft as inverted. The very short time involved and the need to maintain their balance prevented these subjects from giving much thought to the matter, and the influence of the otolith apparatus might explain the differences in their experience.

Simons (5) conducted tests in the identical C-131B aircraft that we used. For his experiments the subjects walked on the overhead, in the weightless phase of the parabolic maneuver, by means of "magnetic shoes." He wrote, "An apparently universal orientation phenomenon was noted by the four subjects participating in this experiment. All subjects reported an immediate spatial orientation of "down" being where their feet were..." One subject reported that the foot-down orientation was strong with his eyes closed and his feet fixed to the walkway. The author, a pilot, had the weird visual experience of looking forward and seeing the pilots sitting upside down: Two subjects walked "spider fashion" (between the floor and ceiling using arms and legs), and one reported that "the walkway became the floor"; the other subject reported a sense of oscillation between the floor and the walkway as being "down."

It would seem reasonable to conclude that if his subjects in weightlessness regarded the overhead walkway as "down," our two subjects who regarded it as "up" were exceptional rather than the three who did not. Although these observations are too limited to draw definite conclusions with regard to the contribution of the vestibular (otolith) organs in the perception of the upright under these circumstances, they do suggest at least that they may have played a role.

III. Restrained in the Weightless Phase of Parabolic Flight

Advantage was taken of an ongoing experiment to collect information on the subject's perception of the upright with reference to the cabin during the weightless phase of parabolic maneuvers. Two naive normal and three of the L-D subjects (HA excepted) participated.

In the primary experiment the subjects' task was to set a dim line of light in the dark to what they regarded as "horizontal" in the weightless phase of the parabola. The signal to make the setting was relayed from the pilot. The target device has been described elsewhere (6). It did not constitute an adequate visual cue to the visual upright; hence, in this experiment the subjects were in "darkness." They were encased in a Fiberglas mold and rigidly secured to a tilt device which in turn was secured to the aircraft about 15 feet aft of the center of gravity in the KC-135. Each subject was exposed to five parabolas while in four different positions with reference to the cabin: upright, and at 30°, 60°, and 90° tilt, making twenty trials in all.

Results. After completion of all trials, each subject was asked whether he experienced any change in body position during the weightless phase of the parabola. The two normal subjects stated that they perceived a change in body position from "head-up" to "head-down" on entering weightlessness and a return to the head-up position on the pull-out. This occurred in every parabolic maneuver regardless of body position in the tilt device. The L-D subjects did not experience a head-down feeling on any occasion.

Incidental Observations

Ample confirmation of these results was provided by Dr. Earl Miller in response to our inquiry. He participated in many flights in which ocular counterrolling was measured during parabolic maneuvers (7). The subjects were rigidly secured to a tilt device just aft of the center of gravity of the C-131B aircraft. Photographs were obtained by a flash unit while the subject fixated a dim point of light. The positions of the subject with reference to the cabin were upright and at 25° or 50° tilt. He clearly recalled that subjects not infrequently volunteered the information that they felt upside down during the maneuver.

Comment. - The findings of this experiment strongly suggest that our normal subjects were responding to sensory information not available to the L-D subjects which must have had its origin in the vestibular apparatus inasmuch as these two groups were alike with respect to the physiologic deafferentation of nonotolithic gravireceptors. There are two reasons for ruling out the semicircular canals as the source. First, the changes in angular velocity were very small, and, second, the perception reported by the subject was that of up-down and not rotation.

Among ten L-D subjects (8), JO had the highest and PE the lowest counterrolling values, with MY's values falling close to the mean. These differences in counterrolling index had no significance in terms of this particular behavioral experience in weightlessness. It raises the question at what counterrolling value, or subgravity level, the inversion illusion may be experienced.

GENERAL DISCUSSION

Although the American astronauts, in describing their experiences in Mercury and Gemini space flights, did not report a feeling of being upside down, comments by Soviet authors on the experience of their cosmonauts during orbital flights are in accord with our experimental findings in parabolic flight. Gazenko (9) writes as follows: "In some of the cosmonauts (G. Titov, A. Nikolayev, P. Popovich) illusory feelings as to the wrong position of the body in space occurred at once, while in other cases, the illusion developed gradually (K. Feoktistov, B. Yegorov)." Vasil'yev and Volynkin (10) add the interesting note that Feoktistov's and Yegorov's illusion of being upside down occurred throughout the period of weightlessness whether their eyes were open or closed. It disappeared only with the beginning of acceleration when the craft was being braked. Of considerable significance too is the cosmonauts' observation that the nature and intensity of the illusion and vertigo were the same in free flight as when the craft was stabilized. Gazenko adds, "It was especially interesting to note that, when the cosmonauts gained a foothold on the chair by straining their muscles, the illusions either diminished or even completely disappeared. This fact underscores the significance of cutaneous and muscle reception in restoring a correct analysis of the position of the body in space."

In weightlessness, with body (head) fixed and without visual cues, knowledge of the upright of the cabin must come from contact with objects whose relation to the cabin has been remembered. These cues, however, must not be confused with normal contact cues, although some of the same sensory receptors may be involved. In weightlessness these cues should be termed agravic contact cues to emphasize qualitative and quantitative differences in the information they furnish. They include agravic touch-pressure, agravic kinesthesis, and their derivative agravic stereagnosis. Bodily movements contribute additional information, and, in the case of the vestibular organs, the stimulus to the semicircular canals on moving the head is normal although the response may be slightly different from normal; the stimulus to the otolith apparatus resulting from body and head movements would of course be greatly different in the absence of gravity.

If it is assumed that conditions existed for Feoktistov and Yegorov in which these nonvisual agravic cues were inadequate for proper orientation to the spacecraft, important questions must be raised. Why should a person feel upside down rather than simply a lack of awareness of the upright? And, if the contact cues did not vary, what precipitated the illusion on one occasion and not another? How are individual differences explained?

The feeling of being upside down with eyes open ascribed to Feoktistov and Yegerov is even more difficult to explain if there were strong visual cues to the upright of the spacecraft. That it lasted for some time was suggested by Gazenko (9), as noted above. Although there are few reports of this inversion illusion in weightlessness in the presence of visual cues, they point to a tendency toward its occurrence. This is extraordinary in view of the great influence of vision in the interaction between visual and gravitational cues not only under normal terrestrial conditions (11) but also under conditions of moderately increased G loadings (12). It suggests that persons in weightlessness are vulnerable to influences which determine the feeling of up or down based on gravitational cues. This "vulnerability" exposed by weightlessness seems to consist of "up-downness" having the character of a qualitative phenomenon. Under the "influences" investigated in parabolic flight it would appear that this vulnerability is greater in normal persons than in persons who have lost the function of the vestibular organs.

REFERENCES

1. Hammer, L. R., Aeronautical Systems Division studies in weightlessness: 1959-1960. WADD TR 60-715. Wright-Patterson Air Force Base, Ohio: Wright Air Development Division, 1961.

2. Graybiel, A., Important problems arising out of man's gravitational-inertial force environment in orbiting satellites. In: Fleisig, R., Hine, E. A., and Clark, G.J.(Eds.), Lunar Exploration and Spacecraft Systems. New York: Plenum Press, 1962. Pp 177-187.

3. Simons, J. C., and Gardner, M.S., Weightless man: A survey of sensations and performance while free-floating. AMRL-TDR-62-114. Wright-Patterson Air Force Base, Ohio: Aerospace Medical Research Laboratories, 1963.

4. Kas'yan, I. I., Kolosov, I. A., Lebedev, V. I., and Yurov, B. N., Reactions of cosmonauts during parabolic flight in aircraft. Izv. Akad. Nauk, SSSR, Series B, No. 2, 169-181, 1965. (Translation)

5. Simons, J. C., Walking under zero-gravity conditions. WADC Technical Note 59-327. Wright-Patterson Air Force Base, Ohio: Wright Air Development Center, 1959.

6. Clark, B., and Graybiel, A., A device to manipulate and to indicate the position of remote test-objects. Amer. J. Psychol., 65:286-287, 1952.

7. Miller, E. F., II, Graybiel, A., and Kellogg, R. S., Otolith organ activity within Earth standard, one-half standard, and zero gravity environments. Aerospace Med., 37:399-403, 1966.

8. Miller, E. F., II, and Graybiel, A., A comparison of ocular counterrolling movements between normal persons and deaf subjects with bilateral labyrinthine defects. Ann. Otol., 72:885-893, 1963.

9. Gazenko, O., Medical studies on cosmic spacecrafts "Vostok" and Voskhod." NASA TT F-9207. Washington, D. C.: National Aeronautics and Space Administration, 1964.

10. Vasil'yev, P. V., and Volynkin, Yu.K., Some results of medical investigations carried out during the flight of Voskhod. NASA TT F-9423. Washington, D.C.: National Aeronautics and Space Administration, 1965.

11. Witkin, H. E., and Asch, S. E., Studies in space orientation. III. Perception of the upright in the absence of a visual field. J. exp. Psychol., 38:603-614, 1948.

12. Graybiel, A., Oculogravic illusion. Arch. Ophthal., 48:605-615, 1952.

Unclassified
Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)* U. S. Naval Aerospace Medical Institute Pensacola, Florida	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP N/A

3. REPORT TITLE
THE INVERSION ILLUSION IN PARABOLIC FLIGHT: ITS PROBABLE DEPENDENCE ON OTOLITH FUNCTION

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*
N/A

5. AUTHOR(S) *(Last name, first name, initial)*
Graybiel, Ashton, M. D. ; Kellogg, Robert S., CAPT USAF

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
20 July 1966	12	12

8a. CONTRACT OR GRANT NO. NASA Order R-93 b. PROJECT NO. MR005.04-0021 c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) NAMI-974 9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)* 134

10. AVAILABILITY/LIMITATION NOTICES
Distribution of this document is unlimited.

11. SUPPLEMENTARY NOTES Joint Report: NAMI, NASA, 6570th Aerospace Medical Research Laboratories	12. SPONSORING MILITARY ACTIVITY

13. ABSTRACT

Observations were made on normal subjects and deaf persons with bilateral labyrinthine defects (L-D subjects) under three different conditions in parabolic flight: 1) free-floating, 2) restrained in a Fiberglas mold, and 3) "standing" on the overhead during a motified parabola generating about -0.05 G unit. There were interindividual differences in the reactions among the normal but not among the L-D subjects. Some normal but none of the L-D subjects experienced a reversal of their personal orientation with regard to up-down under all three conditions. This "reversal" was considered to have its genesis in the vestibular organs, probably the otolith apparatus. Our findings are in accord with Russian reports describing feelings of inversion among cosmonauts in orbital flight. Attention is called to the necessity of distinguishing between information furnished by touch-pressure, kinesthesis, and stereagnosis under ordinary conditions and agravic touch-pressure, agravic kinethesis, and agravic steragnosis.

DD FORM 1 JAN 64 1473

Unclassified
Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Illusions						
Weightlessness						
Vestibular apparatus						
Perception						
Deafness						
Parabolic flight in aircraft						
Information processes						

INSTRUCTIONS

1. ORIGINATING ACTIVITY: Enter the name and address of the contractor, subcontractor, grantee, Department of Defense activity or other organization *(corporate author)* issuing the report.

2a. REPORT SECURITY CLASSIFICATION: Enter the overall security classification of the report. Indicate whether "Restricted Data" is included. Marking is to be in accordance with appropriate security regulations.

2b. GROUP: Automatic downgrading is specified in DoD Directive 5200.10 and Armed Forces Industrial Manual. Enter the group number. Also, when applicable, show that optional markings have been used for Group 3 and Group 4 as authorized.

3. REPORT TITLE: Enter the complete report title in all capital letters. Titles in all cases should be unclassified. If a meaningful title cannot be selected without classification, show title classification in all capitals in parenthesis immediately following the title.

4. DESCRIPTIVE NOTES: If appropriate, enter the type of report, e.g., interim, progress, summary, annual, or final. Give the inclusive dates when a specific reporting period is covered.

5. AUTHOR(S): Enter the name(s) of author(s) as shown on or in the report. Enter last name, first name, middle initial. If military, show rank and branch of service. The name of the principal author is an absolute minimum requirement.

6. REPORT DATE: Enter the date of the report as day, month, year; or month, year. If more than one date appears on the report, use date of publication.

7a. TOTAL NUMBER OF PAGES: The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.

7b. NUMBER OF REFERENCES: Enter the total number of references cited in the report.

8a. CONTRACT OR GRANT NUMBER: If appropriate, enter the applicable number of the contract or grant under which the report was written.

8b, 8c, & 8d. PROJECT NUMBER: Enter the appropriate military department identification, such as project number, subproject number, system numbers, task number, etc.

9a. ORIGINATOR'S REPORT NUMBER(S): Enter the official report number by which the document will be identified and controlled by the originating activity. This number must be unique to this report.

9b. OTHER REPORT NUMBER(S): If the report has been assigned any other report numbers *(either by the originator or by the sponsor)*, also enter this number(s).

10. AVAILABILITY/LIMITATION NOTICES: Enter any limitations on further dissemination of the report, other than those imposed by security classification, using standard statements such as:

(1) "Qualified requesters may obtain copies of this report from DDC."

(2) "Foreign announcement and dissemination of this report by DDC is not authorized."

(3) "U. S. Government agencies may obtain copies of this report directly from DDC. Other qualified DDC users shall request through ________________."

(4) "U. S. military agencies may obtain copies of this report directly from DDC. Other qualified users shall request through ________________."

(5) "All distribution of this report is controlled. Qualified DDC users shall request through ________________."

If the report has been furnished to the Office of Technical Services, Department of Commerce, for sale to the public, indicate this fact and enter the price, if known.

11. SUPPLEMENTARY NOTES: Use for additional explanatory notes.

12. SPONSORING MILITARY ACTIVITY: Enter the name of the departmental project office or laboratory sponsoring *(paying for)* the research and development. Include address.

13. ABSTRACT: Enter an abstract giving a brief and factual summary of the document indicative of the report, even though it may also appear elsewhere in the body of the technical report. If additional space is required, a continuation sheet shall be attached.

It is highly desirable that the abstract of classified reports be unclassified. Each paragraph of the abstract shall end with an indication of the military security classification of the information in the paragraph, represented as *(TS)*, *(S)*, *(C)*, or *(U)*.

There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14. KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, roles, and weights is optional.