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THE EFFECT OF TRANSIENT WEIGHTLESSNESS ON VISUAL ACUITY

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FOREWORD

This report was prepared by the Maintenance Design Section, Engineering Psychology Branch, Behavioral Sciences Laboratory, under Project 7184, "Human Factors in Advanced Flight," Task 71586, "Design Criteria for Ease of Maintenance." Major Leroy D. Pigg served as task scientist. The authors express sincere appreciation to Lt. Donald Ross, who was responsible for the bulk of the subject scheduling and testing, and to the Crew Stations Section of the Engineering Psychology Branch for the scheduling of the C-131B aircraft used in the study. The study was completed in July 1960.

ABSTRACT

Visual acuity was measured on subjects while they were exposed short periods of weightlessness aboard an aircraft flown through "zero-g" trajectories involving transition from 1 g to 2-1/2 g to zero g. Monocular and binocular acuity of near and far vision were measured on both Snellen and checkerboard targets. Control measurements were made on the ground and inflight at 1 g in counterbalanced sequence with the zero-g measurements. Results show that the weightless environment produced for this study has a detrimental effect on visual acuity as measured. The decrement is not considered to have practical significance.

PUBLICATION REVIEW

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THE EFFECT OF TRANSIENT WEIGHTLESSNESS ON VISUAL ACUITY

INTRODUCTION

Many studies have been conducted to determine the effects of sub- and zero-gravity conditions upon the behavior and performance of man. Mental, physiological, and psychomotor performance, locomotion, and other processes have been and are still being investigated. The possible effect of weightlessness upon man's visual capability, specifically his acuity, is of special interest to us.

A survey of the literature shows several studies of visual performance in relation to both increased and subnormal gravity conditions, including zero-gravity (refs. 1, 2, 3, 4). In only one of these, however, was the function of visual acuity itself investigated. This was a study by White and Jorve (ref. 4) in which the effect of increased positive gravitational stress upon acuity for checkerboard targets was investigated experimentally. They used the Bausch and Lomb Orthorater to measure performance of subjects riding a centrifuge and found that "gravitational stress" had a "significant and progressive effect on visual acuity." They hypothesized that the effect resulted from one or more of three factors: (1) involvement of the autonomic nervous system, (2) change in the shape of the eyeball, and (3) displacement of the crystalline lens in the direction of gravity. The last was tentatively accepted by them as the factor which accounted for the decremental effect of positive acceleration on visual acuity.

On the basis of the White and Jorve findings and the results of other studies showing detrimental effects of increased acceleration, it seems reasonable to expect a similar effect on vision from decreased or zero gravity. The zero gravity condition of space flight is a 1 g deviation from the normal gravity environment just as the 2 g condition is a 1 g deviation in the opposite direction. If the "displacement" theory is valid in explanation of the acuity decrement at 2 g, then a change would also be expected at zero g. It is the purpose of this study to determine whether or not such a change occurs when human subjects are exposed to short periods of weightlessness aboard an aircraft.

METHOD

Production of Weightlessness

The weightless environment was produced by flight of a C-131B aircraft through what is known as a "Keplerian trajectory." In this maneuver, the aircraft follows a ballistic trajectory so that objects inside the aircraft are in a state of free fall, thus effectively weightless. The average weightless period was 14 seconds. The aircraft was subjected to a 2-1/2 g positive pull-up immediately prior to and following each zero-g arc,two of which were normally combined for flight efficiency in one double maneuver (figure 1).

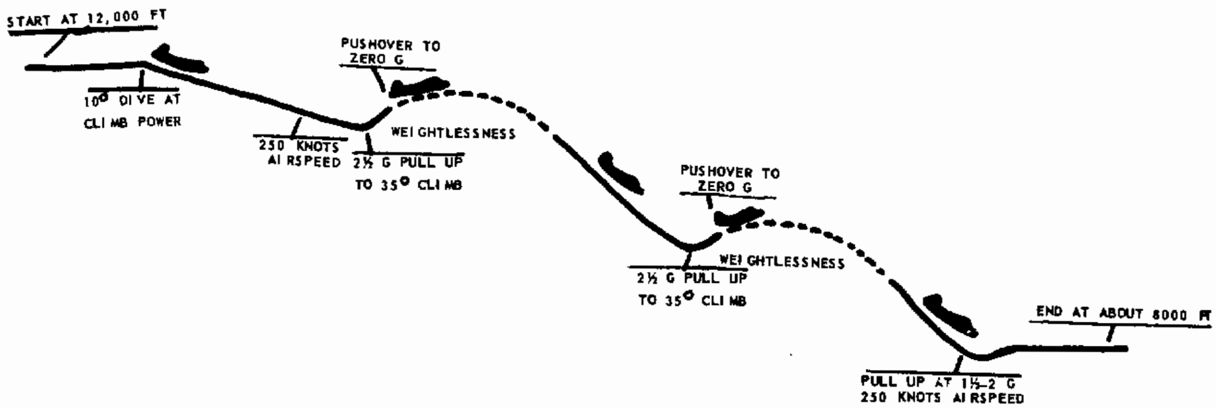

Figure 1. Diagram of Double Zero g Parabola
Produced in the C-131B Aircraft

Apparatus

Two standard vision testers—the Bausch and Lomb "Armed Forces Vision Tester" (fitted for this study with checkerboard targets as used by White and Jorve, figure 2) and the American Optical "Sight Screener" (with Snellen targets) were used. These testers were modified as follows in order to meet certain conditions peculiar to this study:

(1) A timing device was placed in the power source in such a way as to limit target illumination to a 12 second period following power initiation through a switch available to the experimenter. Thus, the targets could be exposed for a constant period within the available period of weightlessness.

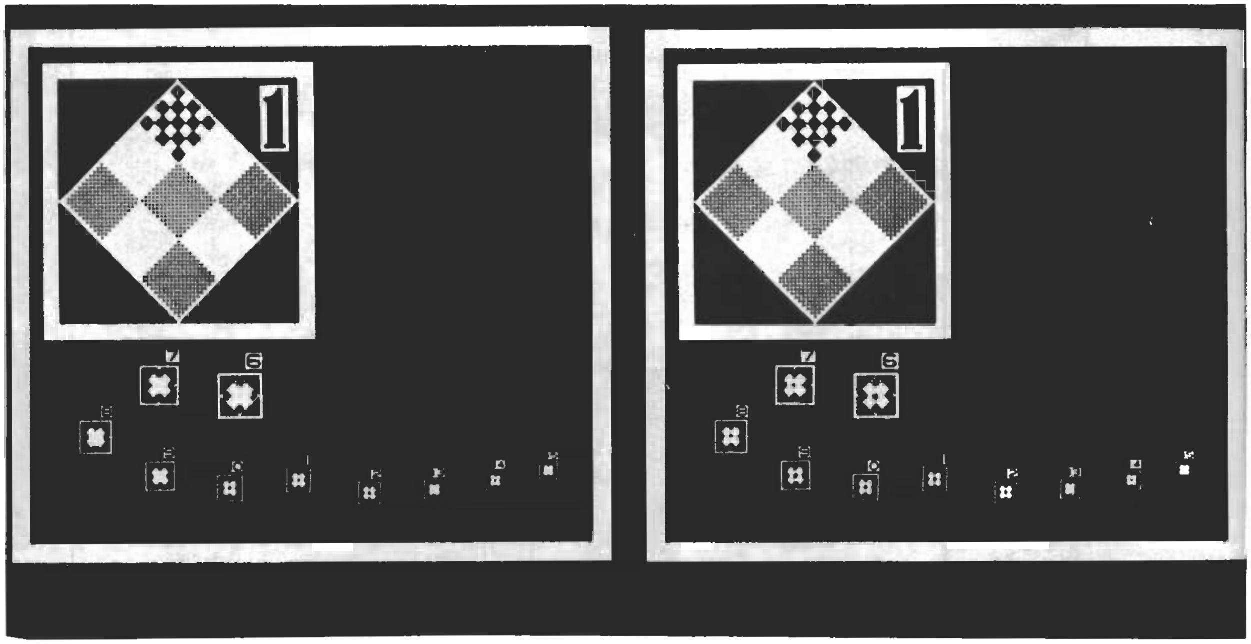

Figure 2. Modified Checkerboard Target used in the Study

(2) On the target plates for left, right, and binocular acuity (near and far), all checkerboard targets subtending more than 1.67 minutes of visual angle and all Snellen targets subtending more than 2.5 minutes of visual angle were blotted out. This was done to prevent subjects from wasting time on noncritical details of the reading task and to insure that each would reach his acuity limit within the time available to him.

(3) A chinrest was initially mounted at each tester for use, in conjunction with the forehead-rest on the tester, in keeping the subject's head in position. Early trials revealed a tendency for the chinrest to induce a vibration different from that of the forehead rest, however, and official trials were conducted with only the forehead rest.

(4) A stop-bar was placed at both the far and near selector handles of the Armed Forces Vision Tester in order to facilitate the selection of the appropriate targets.

(5) The "adjuster" of the Armed Forces Vision Tester (which raised or lowered it in height) was reinforced to prevent the tester from changing position with changes in vertical acceleration during the flights.

The testers were mounted side by side on a rack located at approximately mid-station in the C-131B aircraft. Standard passenger seats with lap belts were provided at the testers. All testing, regardless of the environmental condition employed, was conducted aboard the aircraft with the equipment described here.

Figure 3. Testing of Subject Under Zero g Condition
(Note floating Cardboard tube)

Design

Testing was carried out in three "environments": laboratory 1 g (aircraft on the ground, motionless and quiet), inflight 1 g, and zero g. Order of exposure of subjects to each of these environments was counterbalanced in the following manner:

	Laboratory	Inflight 1 g	Zero g
Group A (N = 12)	1st	2nd	3rd
Group B (N = 12)	3rd	1st	2nd
Group C (N = 12)	2nd	3rd	1st

Twelve subjects were assigned to each group for a total of 36 subjects in the experiment. Each subject was given 6 tests (left, right, and binocular acuity, near and far) with each of the two testing instruments under each environment.

For systematic balance of possible effects of fatigue, practice, etc., presentation of the tests was counterbalanced within each group of subjects as shown in the following diagram:

			Subjects in Each Group											
			1	2	3	4	5	6	7	8	9	10	11	12
Snellen Targets	Near	Left	1	2	3	4	5	6	7	8	9	10	11	12
		Right	2	3	4	5	6	1	8	9	10	11	12	7
		*Binoc	3	4	5	6	1	2	9	10	11	12	7	8
	Far	Left	4	5	6	1	2	3	10	11	12	7	8	9
		Right	5	6	1	2	3	4	11	12	7	8	9	10
		Binoc	6	1	2	3	4	5	12	7	8	9	10	11
Checkerboard Targets	Near	Left	7	8	9	10	11	12	1	2	3	4	5	6
		Right	8	9	10	11	12	7	2	3	4	5	6	1
		Binoc	9	10	11	12	7	8	3	4	5	6	1	2
	Far	Left	10	11	12	7	8	9	4	5	6	1	2	3
		Right	11	12	7	8	9	10	5	6	1	2	3	4
		Binoc	12	7	8	9	10	11	6	1	2	3	4	5

* abbreviation for binocular

The order of testing for every member of the group was unique as shown by the columns. This order was repeated in each of the three counterbalanced environments. Thus, each subject was given each of the 12 separate tests three times.

Subjects

The subjects were civilian and military personnel of WADD. All were cleared for flight in test aircraft and thus had taken required courses in physiological training and altitude indoctrination, in addition to passing medical examinations for flying. The aircraft maneuvers required for production of weightlessness produced nausea in a large proportion of the initially selected subjects and, for this reason, many false starts at acuity testing were made. Data collection was not continued on subjects who became ill. Replacement subjects were used in all such cases until the requirement of the experimental design (for 36 "good" subjects) was met. The ages of the subjects used ranged from 21 to 42 years with a mean of 32.

Although it would have been desirable to use only subjects with normal uncorrected vision, the limited number of available and qualified subjects on flying status made this impossible. Thus, subjects who wore glasses were used along with those who didn't. Those who wore glasses did not necessarily have 20/20 vision. This was also true of those who did not wear glasses. Subjects who wore glasses for any one test were required to use them for all acuity tests. This meant that subjects who did not normally wear correction for far acuity did not wear correction for the near tests.

Procedure

Whenever possible, two subjects were scheduled for a given mission. They were assigned together to one of the experimental groups so that they might be tested under the three "environments" in the same order. Assignment of pairs to groups was balanced until each group had the required 12 "good" subjects. Within a group, assignment to the different orders of acuity tests was random.

Before official testing was started, each subject was briefed on the study and the routine to be followed. As part of this, the instructions (Appendix I) were read to him and he was familiarized with the testing instruments. To make sure he appreciated the task and its temporal requirements, he was given a standard presentation (12-second exposure) of one of the acuity targets and told to read as instructed. The experimenter was thus able to ensure that the subject was ready for official testing.

The subject was seated at the instrument he was to use with the experimenter beside him in the other seat (figure 3). The experimenter manually selected the appropriate test by reference to a specially prepared record sheet. The subject placed his head in position at the instrument at a signal from the experimenter, who operated the switch to illuminate the targets (and start the timer) at the proper time. For the weightless environment, this was immediately after onset of zero g, as determined by experimenter's reference to an accelerometer before him. The experimenter recorded the subject's verbal responses on the record sheet as they were made. After the six presentations were made, subject and experimenter changed seats and the same procedure was followed for the other instrument. The second subject was then tested on both instruments. This routine was followed for each of the three testing environments.

Testing in the zero g environment was carried out during radar monitored zero g maneuvers of the aircraft in a special test-flight area. Tests in the inflight 1 g environment were made as the aircraft proceeded to or from the test-flight area.

The laboratory environment test could only be presented with the aircraft on the ground. As soon as testing started it became clear that it was impractical to land, shut down the aircraft, and then resume flight, as would have been required to present the laboratory environment between the zero g and inflight 1 g environments. For the one group so scheduled, laboratory measurements were made as called for, except that the aircraft remained inflight. These measurements were not used as official data. Thus, the order of exposure to the other two environments was retained according to the design, but the laboratory measurements were short by the data of the 12 subjects for whom these measurements fell in-between measurement at the other environments. This was not considered critical since the remaining laboratory measurements were equally divided between the first and third sequences and would tend to cancel possible order effects.

Each subject was exposed to at least 12 zero g arcs (6 double maneuvers) for accomplishment of the required 12 acuity tests. Since pairs of subjects were used whenever possible, and since not every run was good, many of the subjects were exposed to 24 or more arcs during a mission. When a subject was not engaged in the testing routine he was free to enjoy the experience of weightlessness.

RESULTS

A subject's score on a given test was taken as the visual angle subtended by the smallest target preceding the first target at which a reading or identification error was made. The use of visual angle, as opposed to Snellen or decimal notations, facilitates data reduction and analysis, and simplifies the presentation of results.

Means and standard deviations of acuity scores for the 12 tests under each environment are presented in Table I. The mean acuity scores are plotted graphically in Figure 4, with the scores for far acuity separate from those for near acuity. In Figure 4, and for the remainder of this report, the acuity tests are coded as follows: Snellen target - solid line, checkerboard target - broken line, near test - open symbol, far test - closed symbol, binocular test - circle, right eye test - triangle, and left eye test - square. A glimpse at the curves shows the general tendency toward increased visual angles of targets as the testing environment changes from laboratory to zero g. Thus, a progressive loss of acuity is indicated. As shown by the curves, this loss is generally the same for near and far vision. However, the checkerboard target scores appear to be superior to the Snellen scores at the far distance. There is no such clear differentiation at the near distance. If anything, the Snellen scores are superior at the near distance.

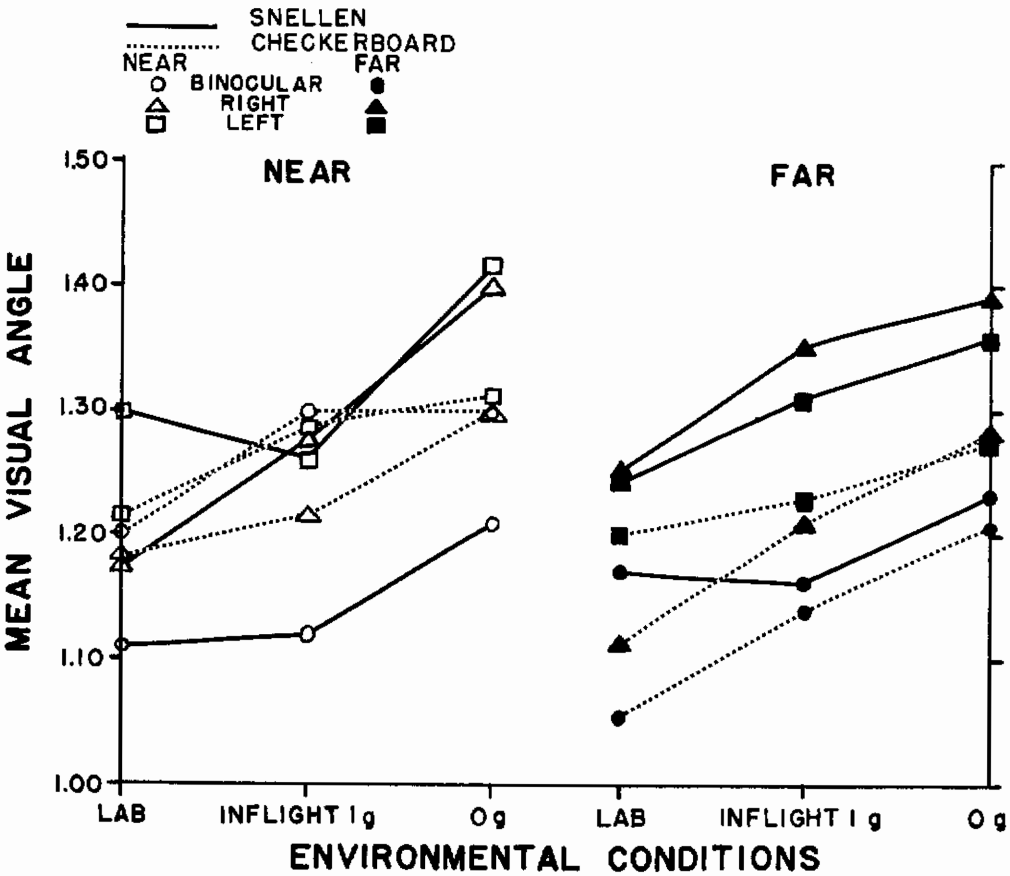

Figure 4. Near and Far Acuity Test Results as Functions of Environmental Change

TABLE I

MEANS AND STANDARD DEVIATIONS OF ACUITY SCORES (IN MINUTES OF VISUAL ANGLE) FOR THREE ENVIRONMENTS

			Lab. (N=24)		Inflight 1 g (N=36)		Zero g (N=36)	
			Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Snellen	Near	Binoc	1.12	0.23	1.13	0.29	1.21	0.28
		Right	1.17	0.29	1.28	0.30	1.40	0.33
		Left	1.30	0.30	1.26	0.30	1.42	0.33
	Far	Binoc	1.17	0.24	1.16	0.27	1.23	0.29
		Right	1.25	0.33	1.35	0.47	1.39	0.32
		Left	1.24	0.27	1.31	0.32	1.36	0.31
Checkerboard	Near	Binoc	1.20	0.16	1.30	0.21	1.30	0.17
		Right	1.18	0.24	1.22	0.20	1.30	0.23
		Left	1.22	0.26	1.29	0.24	1.31	0.26
	Far	Binoc	1.05	0.18	1.14	0.16	1.21	0.18
		Right	1.12	0.29	1.21	0.24	1.28	0.27
		Left	1.20	0.34	1.24	0.26	1.27	0.26

In figure 5, the means of the binocular acuity scores are plotted together for comparison. Again, the general change with environment is apparent, as is the tendency for scores with checkerboard targets to be superior (i.e., smaller visual angles required) at the far distance. The Snellen scores are apparently not so sensitive to distance.

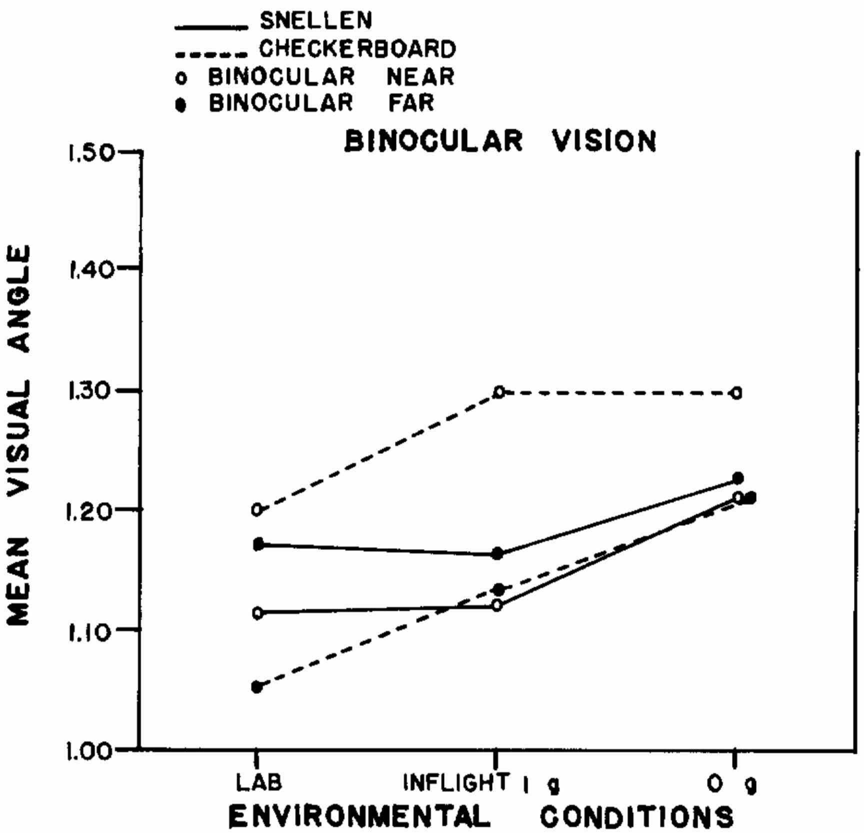

Figure 5. Binocular Acuity Test Results as Functions of Environmental Change

In figure 6, the mean acuity scores are replotted, with those for Snellen targets separate from those for checkerboard targets. The two groups of curves are generally alike in showing the effect of environmental change. The usual superiority of binocular over monocular acuity for both near and far vision is demonstrated in the Snellen grouping. In the checkerboard grouping, however, binocular superiority is found for far vision only.

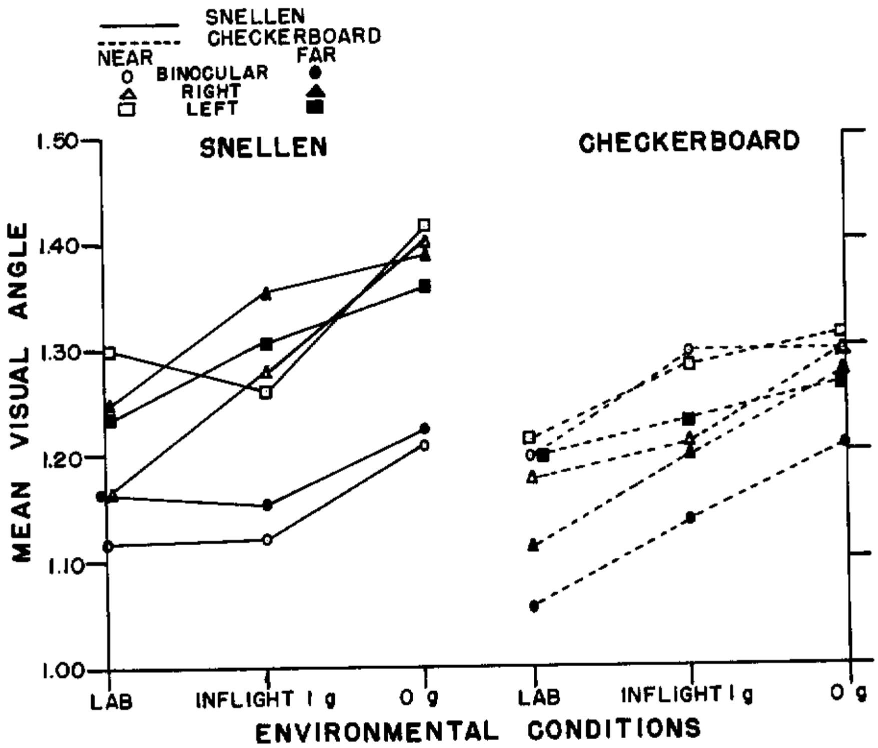

Figure 6. Snellen and Checkerboard Acuity Test Results as Functions of Environmental Change

Table II presents the results of statistical analysis of the effects of the different environments on acuity scores. The t-test for significance of differences between paired observations was used to derive the t-values shown in the table. In this analysis, each subject's score on a given acuity test in one environment is compared with his score on the same test in another environment to arrive at differences between the effects of the environments. Thus, each subject serves as his own standard of comparison and basic inter-individual differences are controlled. This is a very sensitive statistical test for experimental effects.

Two of the 12 tests between laboratory and inflight 1 g scores produced results significant at the 5 percent level of confidence (for two-tailed test). Both tests were for differences between checkerboard scores, for which all six t-values are positive. For checkerboard targets, then, there is evidence that acuity is differentially affected by the 1 g environment of flight, as compared with the laboratory environment representative of the usual testing situation.

TABLE II

"t" VALUES FROM TESTS OF DIFFERENCES BETWEEN PAIRED ACUITY SCORES FOR THREE ENVIRONMENTS

			Lab vs Inflight 1 g (df = 23)	Lab vs 0 g (df = 23)	Inflight 1 g vs 0 g (df = 35)
Snellen	Near	Binoc	0.67	2.25**	1.20
		Right	0.86	1.75*	2.40**
		Left	-0.43	2.00*	4.00***
	Far	Binoc	-0.20	0.71	1.50
		Right	1.38	2.60**	0.60
		Left	0.71	2.75**	1.00
Checkerboard	Near	Bionc	2.75**	3.67***	0.00
		Right	1.00	2.75**	2.00**
		Left	1.20	4.33***	0.50
	Far	Binoc	3.33**	4.50***	2.33**
		Right	2.00*	3.25**	1.76*
		Left	2.00*	1.43	0.75

* $p < .10$ ** $p < .05$ *** $p < .01$

Between laboratory and zero g scores, 8 of the 12 t-values are significant at or beyond the 5 percent level. Five of these eight significant differences were found with checkerboard targets. All 12 t-values are positive and, with one exception, high. This is strong evidence that the zero g environment has a systematic effect on visual acuity by comparison with the laboratory environment. Appendix II presents comparative distributions of laboratory and zero g scores for the near-left test with both Snellen and checkerboard targets.

For inflight 1 g versus zero g scores, 4 of the 12 t-values are significant, 2 for each target type. Again, all 12 t-values are positive. These results suggest that the zero g environment produces a systematic effect on visual acuity beyond the effect of the inflight 1 g environment.

The predominance of significant differences between checkerboard scores at the different environments points to a need for tests of differences between target types. Table III presents the results of t-tests of differences between Snellen and Checkerboard scores for each test condition under each environment. Five of the 36 values are at the 5 percent level of significance while 3 other values approach significance. Negative t-values reflect larger visual angles for Checkerboard targets. These results are inconclusive. They do support the conclusion reached tentatively on the basis of inspection of the curves of figure 2, that smaller visual angles are required for Checkerboard targets read at far distance in all environments. They also support the observation that Snellen targets may be read better at near distance than Checkerboard targets.

TABLE III

"t" VALUES FROM TESTS OF DIFFERENCES BETWEEN PAIRED ACUITY SCORES FOR SNELLEN VS. CHECKERBOARD TARGETS

		Lab (df=23)	Inflight 1 g (df=35)	Zero g (df=35)
	Binoc	-2.00*	-3.00***	-1.80
Near	Right	-0.20	1.20	2.00**
	Left	1.33	-0.50	2.20***
	Binoc	3.00**	0.50	0.40
Far	Right	1.86*	2.00**	1.67
	Left	0.50	1.17	1.80

* $p < .10$ ** $p < .05$ *** $p < .01$

The data of Table II offer no evidence that near and far acuity are differentially affected by change in environment. The significant differences between environments appear to be randomly divided between the near and far tests. This is in agreement with the conclusion reached from inspection of the curves of figures 4, 5, and 6, in which change in environment is seen to produce the same general effect on scores of all tests of acuity.

As a further test of the general effect of environmental change, the nonparametric "sign test" was applied to the data of Table I. This test shows significant differences between scores with the 12 different tests under zero g and the corresponding scores under both the laboratory and inflight 1 g environments. The differences between inflight 1 g and laboratory scores are also significant with this test. These results reflect the fact that every mean score under zero g is equal to or higher than the corresponding mean of either of the other two environments, while 10 of the 12 means under the inflight 1 g environment are higher than the corresponding laboratory means.

DISCUSSION

The results of this study indicate rather clearly that short-term exposure to weightlessness aboard an aircraft has a detrimental effect on visual acuity during the period of exposure. This effect is most dramatic when acuity under the zero g condition is compared with acuity under the laboratory condition, but it is also evident when a comparison is made with acuity measured inflight at 1 g. In the first case, the decrement is compounded with the effect on visual acuity of just being airborne (noise, vibration, etc.,). In the latter case, however, the difference must be attributed largely to the reduction in the gravity environment.

A majority of the significant differences between environments were based on acuity scores for Checkerboard targets. The Checkerboard test thus appears to be more sensitive to environmental effects on acuity than the Snellen test. As pointed out earlier, the Checkerboard targets were read with generally smaller visual angles at the far distance. But the difference between Checkerboard and Snellen scores is especially apparent in the laboratory environment, in which Checkerboard scores tend to be lower for both far and near tests. It might be more precise, therefore, to say the Checkerboard acuity test is the more sensitive measure of differences between static (laboratory) and dynamic (inflight) environments.

White and Jorve, also using Checkerboard targets, found a detrimental effect of increased positive g. A comparison between the effect they found at 2 g (1 g above normal) and the effect found in this study with Checkerboard targets at zero g (1 g below normal) is in order. The White and Jorve scores for the seated position at 1 g and 2 g are converted to visual angles for comparison with the laboratory and zero g scores of this study. (The 1 g environment of the White and Jorve study was equivalent to the laboratory environment of this study.) The results are shown in Table IV.

TABLE IV

CHECKERBOARD ACUITY SCORES (MEAN VISUAL ANGLE IN MINUTES) FROM WHITE AND JORVE STUDY AND COMPARISON SCORES FROM PRESENT STUDY

	White and Jorve			Pigg and Kama		
	Lab.	2 g	Difference	Lab.	0 g	Difference
Binoc	0.91	0.98	0.07	1.20	1.30	0.10
Right	0.94	1.06	0.12	1.18	1.30	0.12
Left	0.88	0.94	0.06	1.22	1.31	0.09
Binoc	0.86	0.96	0.10	1.05	1.21	0.16
Right	0.89	1.06	0.17	1.12	1.28	0.16
Left	0.85	1.00	0.15	1.20	1.27	0.07
			MEAN 0.1117			MEAN 0.1167

The mean difference between the scores at the two environments of the White and Jorve study is 0.1117 minutes of visual angle while for the present study, it is 0.1167 minutes of visual angle. The exactness of the agreement between the two studies is more apparent than real, however. If account is taken of the better average acuity of the White and Jorve subjects, it is clear that their mean decrement of 0.1117 minutes represents a considerably greater percentage loss than does the slightly greater absolute loss found in the present study. White and Jorve used a smaller sample of subjects who had been thoroughly screened for good uncorrected vision. The difference between subject groups shows up as the vertical difference between the two sets of curves in figure 7, in which the means of Table IV are plotted for graphic comparison. In spite of the difference between subject groups, it is clear from the slopes of the curves of figure 7 that a change from the normal gravity environment of one unit of g in either direction produces a comparable decrement in visual acuity.

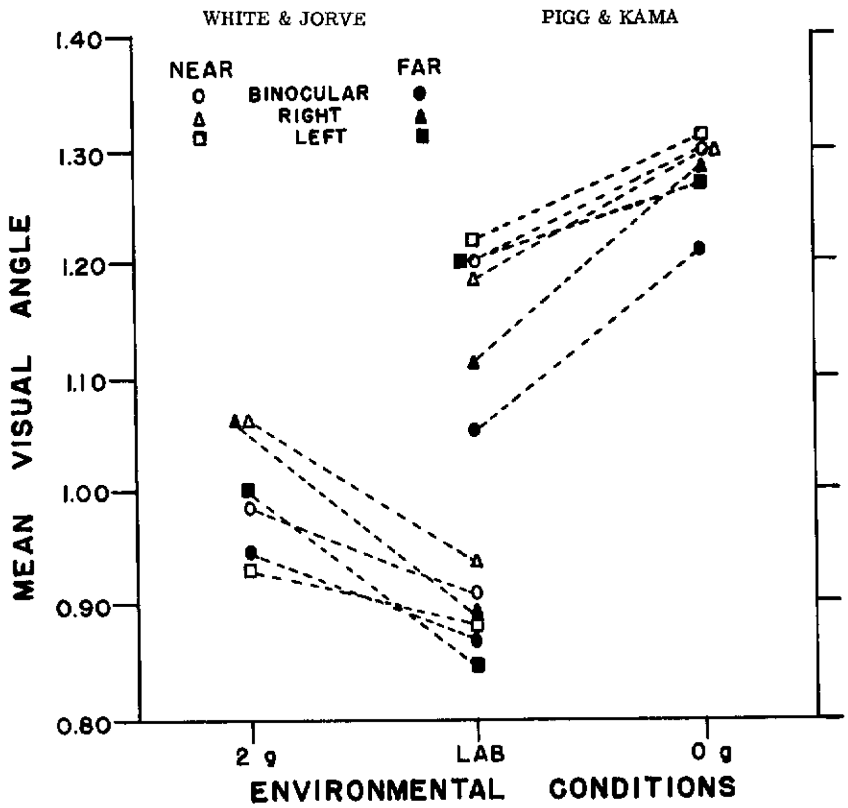

Figure 7. Acuity Test Results From Two Studies as Functions of Environmental Change

The curves of White and Jorve, when extended for higher levels of positive g, continue to rise. Thus, for +3 g they show a further decrement in visual acuity. At this point, the environment is two units of g changed from the normal environment. If extrapolation of the data of the present study were made for the -1 g environment (also two units of g removed from normal, but in opposite direction) we would, accordingly, project a similar further decrement. It would not be difficult to verify the extrapolation since the -1 g environment can be achieved, effectively, by testing subjects while they are inverted in the normal gravity environment. Testing could also be carried out on a centrifuge with the cab oriented for negative g. This, of course, would allow extension of acuity curves for extra units of g in the direction opposite that studied by White and Jorve. It would be interesting to see if visual acuity curves plotted across the complete spectrum of tolerable g would be symmetrical "V" or "U" shapes with low points at the normal environment of 1 g.

CONCLUSIONS

Visual acuity, as measured with the Sight Screener and the Vision Tester (with checkerboard slides) installed in a C-131B aircraft, is decrementally affected during exposure of subjects to short periods of weightlessness in that aircraft.

The decrement is not considered to be of practical significance. When zero-g scores are compared with control scores at 1 g in flight the loss is of the order of 6 percent change in visual angle of targets at threshold acuity.

When acuity at zero g is compared with acuity in a laboratory environment the loss is approximately 10 percent. This loss is similar to that found in another study in which acuity at +2 g was compared with laboratory acuity. Thus, changes of one unit of g in either direction from the normal gravity environment result in comparable losses in visual acuity.

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APPENDIX I

VISUAL ACUITY TESTING INSTRUCTIONS

You are to be given a visual acuity test. The purpose of this test is to discover the differences, if any, of visual acuity under laboratory, regular flight, and zero g flight conditions. As this testing has nothing whatever to do with how good or bad your eyes are, but rather is intended only to discover the differences, if any, found under these three sets of conditions. We ask you to be quick, accurate, and completely honest in your responses.

You are to be tested on two machines. The green machine will display rows of letters. You are to read these letters, from left to right, until it is impossible for you to make out any further lettering or time runs out. You will have a 12-second time limit, so speed and accuracy are essential.

The gray machine will present a series of diamonds with squares making up the interior of these diamonds. One corner of the diamond will have a checkerboard square in it. (Show accompanying chart to subject.) (Figure 8)

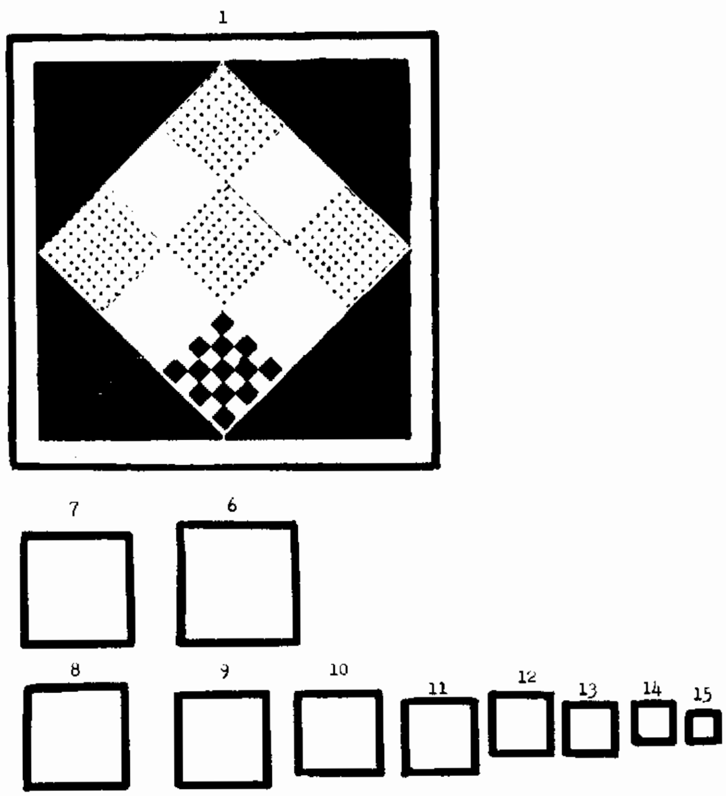

Figure 8. Chart for Briefing Subjects on Checkerboard Targets

You are to tell me which corner this checkerboard is in; top, bottom, left or right. The checkerboard will never be in the middle. The large square numbered 1 (one) will enable you to focus your eyes. This focusing should take only a fraction of a second. You are not to read this square, but rather start with the next largest of the squares (No. 6) as quickly as you have focused your eyes. When you start reading, give the number of the square and then the corner in which the checkerboard is located. For example, 6-bottom, 7-left, 8-right, and so on. Proceed in numerical order to as small a square as you can make out before time runs out. You again have a 12-second time limit.

You will be given tests twice again on these same two machines under two more different environmental conditions. Therefore, we will not discuss results with you nor tell you whether you are right or wrong until the entire series of tests has been given.

Are you ready to begin?

APPENDIX II

A LOOK AT THE DISTRIBUTION OF TEST SCORES FOR ONE TEST

We felt it would be interesting to look at the distributions of scores for one of the specific tests employed in the study. Frequency distributions for the near-left acuity test scores with both the Checkerboard and Snellen targets were plotted for comparison of laboratory and zero-g results.

Figure 9 shows the frequency distributions of the Snellen near-left test scores for both environments. The graphs follow the curve for a normal distribution acceptably well. The distribution shift towards larger visual angles for the zero-g condition is apparent.

In figure 10, the distribution of the checkerboard near-left test scores are shown. Again, we note the apparent normality of the distributions and the distribution shift for the zero-g condition.

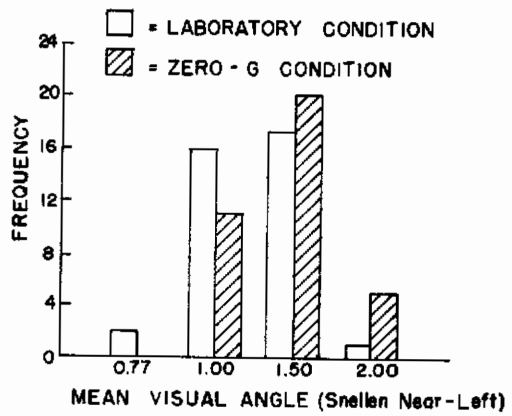

Figure 9. Frequency Distributions of the Snellen Near-Left Test Scores

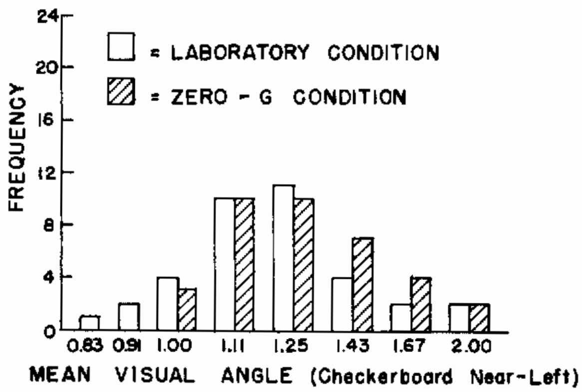

Figure 10. Frequency Distribution of the Checkerboard Near-Left Test Scores