FOREWORD

This report was prepared by the Maintenance Design Section, Human Engineering Branch, Behavioral Sciences Laboratory, under Project 7184, "Human Performance in Advanced Systems," Task 718406, "Design Criteria for Ease of Maintenance," with Major Leroy D. Pigg as Task Scientist. William N. Kama served as study coordinator. Valuable assistance in the testing of subjects and reduction of data was provided by Donald McKechnie of the Maintenance Design Section. The study was initiated in September 1961 and completed in November 1961.

ABSTRACT

The Armed Forces Vision Tester, fitted with checkerboard targets, was used in tests of visual acuity under viewing conditions involving various combinations of gravity effects. Twenty-four subjects were tested for left, right, and binocular acuity of near and far vision in each of four body positions: standing upright, prone, supine, and inverted upright. The latter condition effectively produced -1 G acceleration. Intercomparisons of scores from these positions form the basis for useful generalizations concerning the effects on visual acuity of various acceleration environments, including 0 G. By comparison with their acuity at 1 G, subjects experience a decrement at -1 G of approximately 15 percent. This is comparable to the decrement found by other investigators at 3 G's. Since both -1 G and 3 G's are 2 G-units removed from 1 G, it appears that equal changes in either direction from the normal acceleration environment produce equal losses in visual acuity as a function of the amount of change. This conclusion is supported by results of a previous study of acuity at 0 G, in which a small but statistically significant decrement comparable to that at 2 G's was found.

PUBLICATION REVIEW

This technical documentary report has been reviewed and is approved.

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VISUAL ACUITY IN RELATION TO BODY ORIENTATION AND G-VECTOR

INTRODUCTION

There is general interest in the effects which space flight may have on human performance. Of special interest are the effects of various G-forces——increased, subnormal, and weightlessness——on man's visual capability.

Visual performance under different accelerative forces has been investigated experimentally in several studies (refs. 1-6). Two of these were concerned with visual acuity: (a) White and Jorve (ref. 6) made measurements under conditions of increased positive G and found that gravitational stress has a "significant and progressive effect on visual acuity." (b) We measured acuity (ref. 4) under conditions of weightlessness aboard an aircraft and found that "visual acuity... is decrementally affected during exposure of subjects to short periods of weightlessness...." We also noted that the loss in acuity at 0 G, by comparison with normal 1 G acuity, is similar to the loss found at 2 G's. We concluded that "...changes of one unit of G in either direction from the normal gravity environment result in comparable losses in visual acuity."

The data of White and Jorve for higher levels of positive G show increasingly larger visual angles. Thus, for 3 G's they show a further decrement in visual acuity. At this point, the environment is 2 units of G changed from the normal environment. If extrapolation of our 0 G data were made for the -1 G environment (also 2 units of G removed from normal, but in opposite direction), we would, accordingly, project a similar further decrement.

It is not difficult to test the validity of the extrapolation, since the -1 G environment can be achieved, in effect, by inverting subjects in the normal gravity environment. The acceleration vector is thus from foot to head in contrast to the normal acceleration of the body in the upright position. This report deals with visual acuity in this -1 G condition compared with acuity in other acceleration environments.

METHOD

Apparatus

The Bausch and Lomb "Armed Forces Vision Tester," fitted with checkerboard targets as shown in figure 1, was used for all acuity measurements. This apparatus was used to allow comparison of test results with those of the previous studies (refs. 4 and 6) in which the same "tester" was used.

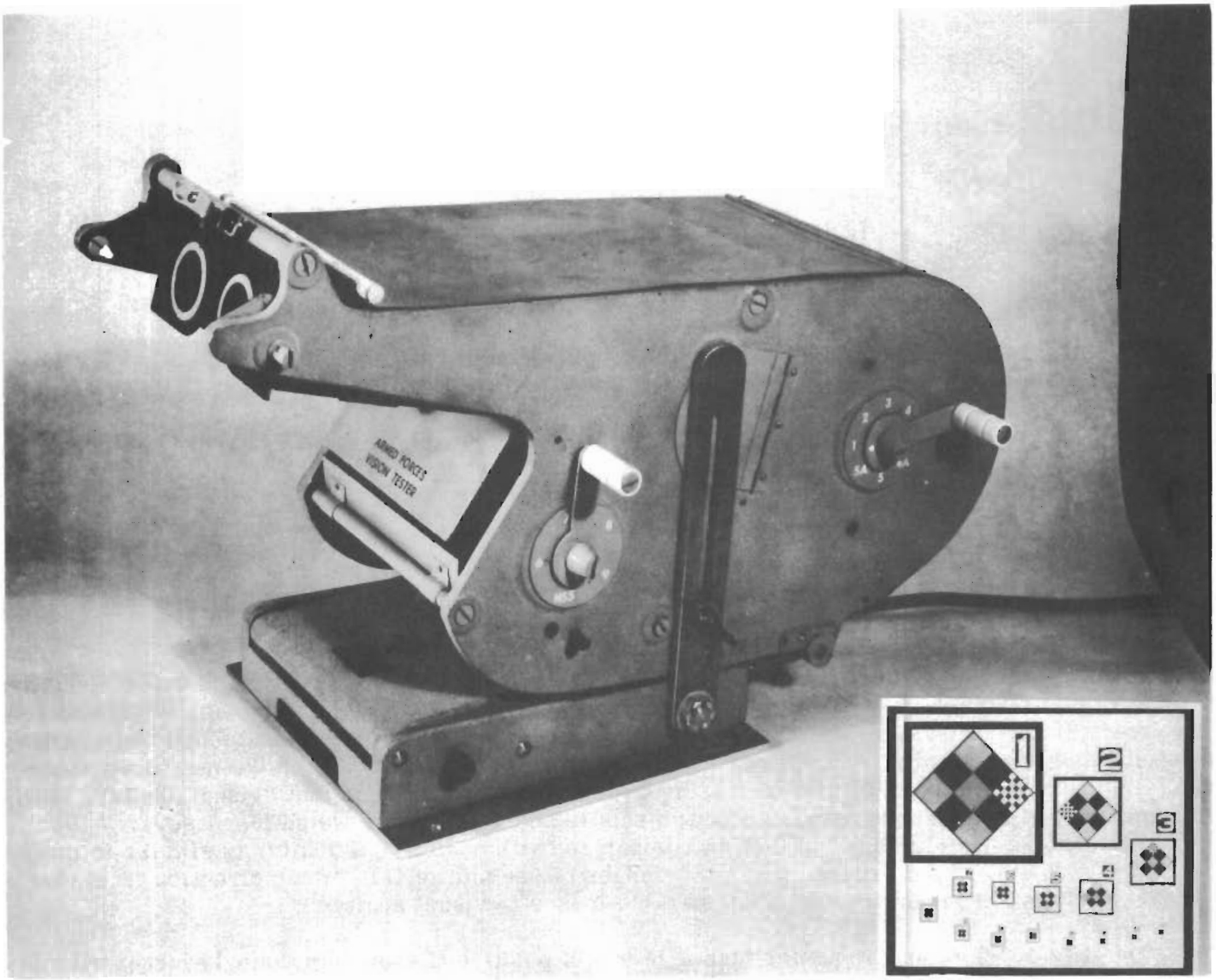


Figure 1. Vision Tester and Checkerboard Target

Two other devices were used in this study——a tilt table and a fixed low platform. They were employed in setting up each of the different viewing conditions. The tilt table, a wooden platform mounted on a metal framework with a single rotational axis, which allowed rotation from a horizontal to a vertical position, was used to place the subject in the inverted viewing position. It was fitted with a parachute harness which was worn by subjects as a means of body restraint in the inverted position.

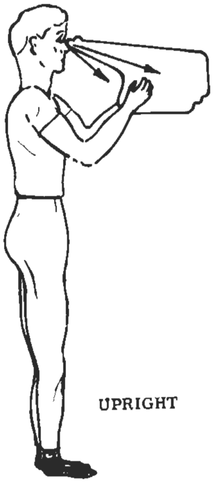
The low platform consisted of a board, 20 inches wide and 72 inches long with a padded surface, mounted approximately 8 inches high. It was used to support subjects in both prone and supine viewing positions. The various configurations of vision tester and platforms for the different viewing conditions are shown in figures 2 and 3.

UPRIGHT

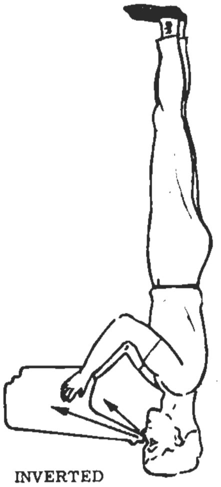
INVERTED

PRONE

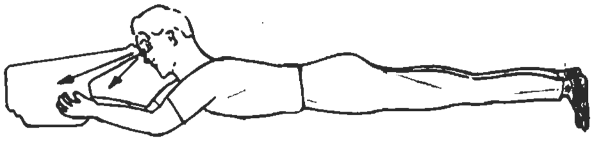
Figure 2. The Four Viewing Conditions



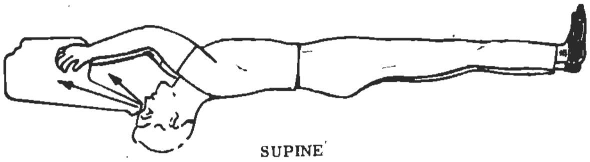
UPRIGHT



INVERTED



PRONE



SUPINE

Figure 3. Actual Tests under the Four Viewing Conditions

Design

Acuity testing was carried out under four viewing conditions: (a) upright——subject in normal standing position, tester upright; (b) inverted——subject suspended on tilt table, head down and feet up, tester inverted; (c) prone——subject lying on stomach on low platform with head erect, tester upright; and (d) supine——subject lying on his back on low platform with head back and down (and resting on pillow on floor), tester inverted. These conditions are depicted in figure 2. Photographs of the actual configurations are included in figure 3.

The line of sight to the test targets was maintained approximately perpendicular to the gravity vector in all test conditions. Thus, the force of gravity was toward the "bottom" of the eyeball for the upright and prone conditions and toward the "top" of the eyeball for the supine and inverted positions. To achieve these relationships for the prone and supine conditions, it was necessary to allow slight upward rotation of the eyeballs, in addition to the backward head rotation mentioned previously.

The upright and prone conditions provided control data for the normal 1 G environment at the eye. In the prone condition, however, the hydrostatic effect of the upright body was neutralized. The inverted and supine conditions provided data for the -1 G environment at the eye, with the hydrostatic effect again neutralized in the latter condition. Thus, several complementary pairs of test conditions were possible.

The order of exposure of subjects to each of these viewing conditions was counterbalanced in the following manner:

	Upright	Inverted	Prone	Supine
Group A (N=6)	1st	2nd	3rd	4th
Group B (N=6)	2nd	3rd	4th	1st
Group C (N=6)	3rd	4th	1st	2nd
Group D (N=6)	4th	1st	2nd	3rd

Six subjects were assigned to each group for a total of 24 subjects in the experiment. Each subject was given 6 tests (left, right, and binocular acuity, near and far) in each of the four viewing conditions.

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 Group					
		1	2	3	4	5	6
Near	Left	1	2	3	4	5	6
	Right	2	3	4	5	6	1
	Binocular	3	4	5	6	1	2
Far	Left	4	5	6	1	2	3
	Right	5	6	1	2	3	4
	Binocular	6	1	2	3	4	5

The order of testing for every member of the group was unique as shown by the columns of the diagram. This order was repeated in each of the four counterbalanced viewing conditions. Thus, each subject was given each of the six separate acuity tests four times.

Subjects

The subjects were male civilian and military personnel of the 6570th Aerospace Medical Research Laboratories and male undergraduate students from the University of Dayton. All were selected on the basis of having (in their opinion) normal, uncorrected vision. Their ages ranged from 19 to 41 years with a mean of 24.

Procedure

Two or more subjects were scheduled for testing each day. They were assigned together to one of the experimental groups so that they might be tested under the four viewing conditions in the same order. Assignment to groups was balanced until each group had the required six subjects. Within a group, assignment of the different orders of acuity tests was random.

As they arrived, subjects were taken to the testing room where they were briefed on the purpose of the study, the apparatus to be used, and the manner in which they were to make their responses. They were given a familiarization test with sample checkerboard targets in connection with the reading of the following instructions:

> *You are to be given a series of visual acuity tests. The purpose of these tests is to discover the differences, if any, in visual acuity under different conditions of viewing. The tests have nothing to do with how good or bad your eyes are; they are to be used only for comparison between the different conditions of viewing. Please be quick, accurate, and completely honest in your responses.*
>
> *The instrument to be used in this test will be the Bausch and Lomb Orthorater. This instrument will present a series of diamonds with squares making up the interior of these diamonds. One corner of each diamond will have a checkerboard square in it. (Chart is shown to subject.)*
>
> *You are to tell me which corner this checkerboard is in: top, bottom, left, or right. The checkerboard will never be in the middle. When you start reading, give the number of the square and then the corner in which the checkerboard is located; for example, 1-top, 2-left, 3-right, and so on. (Sample targets are shown to and read by subject.) Proceed in numerical order to as small a square as you can make out.*
>
> *You will be given three more tests on this instrument at three other positions. Because of this, we cannot discuss results with you or tell you whether you are right or wrong until the entire series of tests has been given.*
>
> *Are you ready to begin?*

They were then tested one at a time (with the other subjects absent from the experimental area) under the first of the four viewing conditions. When all had been tested under the first condition, they were tested in the same order under the second condition, and so on through all four conditions. The experimenter selected each test in appropriate order by reference to a specially prepared record sheet on which the verbal responses of each subject were recorded as they were made.

Since the different viewing conditions required different head positions, the position of the tester had to be changed accordingly. Thus, although the tester was set upright for the standing and prone conditions, it had to be placed upside down for the inverted and supine conditions. This was facilitated by the use of special props of appropriate height and angle. In all cases, the subject's line of visual regard was kept approximately perpendicular to the gravity vector (see figure 2).

RESULTS

A subject's score on a given test was taken as the visual angle (in minutes) subtended by the smallest target preceding the first target incorrectly identified. The use of visual angle, as opposed to Snellen or decimal notations (nonlinear transformations of visual angle), facilitates data reduction, lends validity to statistical analysis, and simplifies the presentation of results.

The means of the 24 acuity scores for each of the viewing conditions are presented in table I. They are presented graphically in figure 4. The results indicate a progressive loss in acuity as the testing condition is changed from upright to prone to supine to inverted. The loss is general; i.e., it is reflected in the scores from each of the six tests. The data show the usual superiority (smaller visual angles) of binocular scores over monocular scores obtained at the same reading distance. Further, they show a distinct differentiation between near and far scores, with the latter reflecting smaller visual angles generally, but indicating that far acuity suffers somewhat greater loss with changes in viewing conditions than does near acuity. Thus, the threshold visual angle for far vision in the inverted viewing condition averages 19 percent greater than in the upright condition, whereas the comparable increase for near vision is only 13 percent.

TABLE I

MEANS OF ACUITY SCORES FOR FOUR VIEWING POSITIONS

(in minutes of visual angle)

		Upright	Prone	Supine	Inverted
Near	Left	1.17	1.24	1.28	1.32
	Right	1.21	1.23	1.25	1.33
	Binocular	1.16	1.18	1.26	1.28
Far	Left	1.02	1.12	1.18	1.20
	Right	0.94	0.99	1.02	1.16
	Binocular	0.91	0.96	1.01	1.08

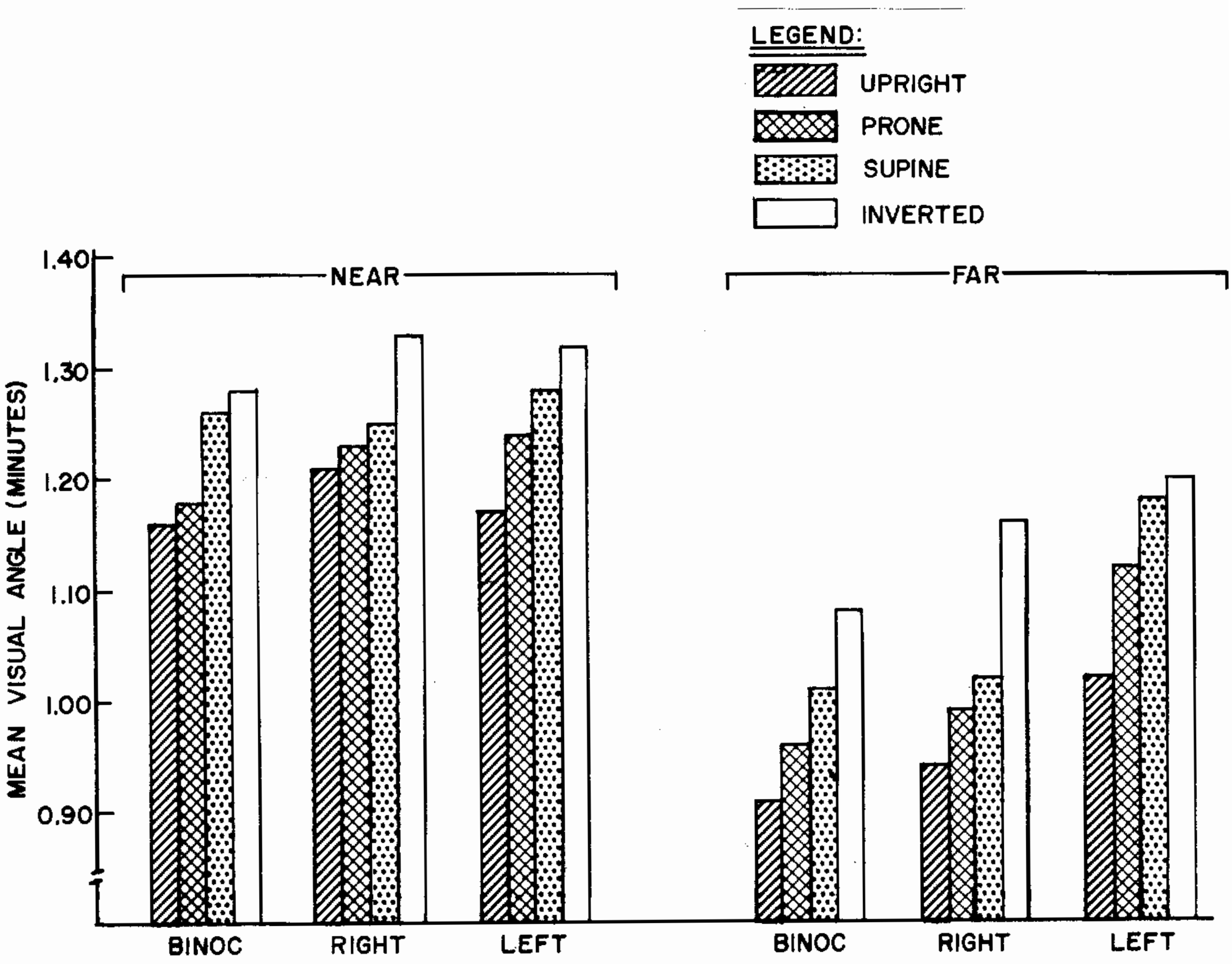


Figure 4. Acuity Test Results in Relation to Viewing Conditions

Table II presents the results of statistical analysis of the effects of the different viewing conditions on acuity scores. The t-test for significance of difference between paired observations was used to derive the t-values. In this analysis, each subject's acuity score for a given test under one viewing condition is compared with his score for the same test under a different viewing condition 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.

Comparisons between scores for the upright condition and for the inverted condition show highly significant differences in favor of the upright condition. Five of the six t-values are significant at or beyond the 5 percent level of confidence (for two-tailed test) and the remaining value approaches significance.

Four out of the six comparisons between scores for the upright and supine viewing conditions are significant in favor of the upright condition. The other two differences, while not significant, are in the same direction.

Thus, the upright condition, which may be considered as the normal 1 G condition, produces scores significantly better than those from either condition (inverted or supine) in which -1 G environment is present at the eye.

TABLE II

t-VALUES FROM TESTS OF DIFFERENCES BETWEEN PAIRED ACUITY SCORES FOR FOUR VIEWING CONDITIONS (N=24)

		COMPARISONS †					
		Upright vs Inverted	Upright vs Supine	Upright vs Prone	Prone vs Inverted	Prone vs Supine	Supine vs Inverted
Near	Left	3.27**	2.62*	1.84	2.22*	1.10	1.16
	Right	2.01	0.77	0.41	1.56	0.33	1.86
	Binocular	4.41***	3.70**	0.71	5.88***	2.19*	0.74
Far	Left	3.06**	5.00*	2.51*	1.48	1.39	0.34
	Right	2.61*	1.07	2.67*	1.93	1.10	1.60
	Binocular	5.01***	4.54***	2.94**	3.75***	1.89	1.71

Two-tailed test
*p < .05
**p < .01
***p < .001

† All mean differences and, thus, all t-values are positive in favor of the condition listed first in each column heading.

In table II we see that the upright condition also results in scores somewhat better than does the prone position, especially in the matter of far acuity. All t-values for comparisons between these conditions are positive, the three for far acuity significantly so. These results indicate more than just the superiority of scores from the upright condition over those from the prone condition. They make it apparent that the general superiority of the upright condition cannot be explained solely on the basis of the advantage accruing from the 1 G environment at the eye, for the prone viewing condition also involves the 1 G environment at the eye. An attempt at partial explanation of these results in terms of both acceleration and hydrostatic effects is included under "Discussion."

Results of comparisons between prone position scores and scores from each of the -1 G conditions are shown in the 4th and 5th columns of table II. Three t-values are significant in favor of the prone scores over the inverted scores, while the remaining three t-values are high and positive (in the same direction). Only one of the t-values for prone versus supine comparisons is significant, but another approaches significance, and all are positive in favor of the prone condition. Thus, even though they are inferior to the upright scores, the prone scores are clearly superior to scores for the -1 G conditions.

The remaining comparison is that between supine and inverted scores as shown in the last column of table II. None of the t-values is significant. However, three are high and all are positive in favor of the supine condition over the inverted condition. This evidence suggests that there is a small but real improvement to be gained by neutralizing the hydrostatic effect of body position for -1 G viewing conditions.

DISCUSSION

Taken together, the results seem to confirm the existence of a hierarchy of viewing conditions from upright to prone to supine to inverted, with respect to their relative favorableness for visual acuity. The fact that there is a hierarchy, and not a dichotomy, between the scores from the -1 G condition and those from the 1 G condition suggests that scores are influenced by a variable other than the acceleration environment at the eye. To be sure, acceleration has a significant effect, for the upright and prone conditions both produce clearly superior scores by comparison with either the inverted or supine conditions. But the acceleration environment at the eye accounts for only part of the order of increasing effects respective to the upright, prone, supine, and inverted viewing conditions.

The hydrostatic effect of body position may be useful in explanation of the phenomenon. If we assume that the upright body position is the normal position (see Appendix for defense of this assumption), then, of the three other viewing conditions, the inverted condition would represent the greatest hydrostatic deviation from normal. The prone and supine conditions would be equally intermediate in this respect. Now, if visual acuity is decrementally affected by hydrostatic deviation from the upright condition, we would expect a decrement of a certain size between upright scores and both prone and supine scores, and a greater decrement between upright and inverted scores. If we now add the decrement resulting from the -1 G condition, as appropriate, to each of the decrements from hydrostatic deviation, we arrive at the hierarchy of scores for the four conditions. Thus, the prone scores are worse than the upright scores by the amount of the intermediate hydrostatic effect; the supine scores are worse by the amount of the -1 G decrement plus the intermediate hydrostatic effect; and, finally, the inverted scores are worse by the sum of the -1 G effect and the maximum hydrostatic effect.

If we glance back at figure 4, we can see graphically how the decremental effects operate. The prone scores are 5 percent greater (poorer visual acuity) on the average than the upright scores. This is the intermediate hydrostatic effect.* The supine scores are about 5 percent greater than the prone scores. This is the "pure" -1 G effect. The inverted scores add another 5 percent to the supine scores. This is the increment in hydrostatic effect brought about by the additional 90° rotation of the body.

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* The difference between the upright and prone scores could have been influenced by either the head rotation or the eye rotation (or both) required in the prone viewing condition (see "Design," page 4). Neither the direction nor the extent of any such influence is known. It would have affected the scores from the supine condition precisely the same (i.e., either favorably or unfavorably), for the prone and supine viewing configurations were identical except for the direction of gravity. Furthermore, the influence, if any, could have no bearing on the more vital comparison between scores from the upright and inverted viewing conditions, for these configurations were also identical except for the direction of gravity.

One other point should be made relative to possible influences of eye rotation in the prone and supine conditions. The line of sight for far targets was not the same as for near targets. Thus, a certain amount of eye rotation was involved just in shifting between the two distances. If the further rotation for the prone and supine conditions were to influence the results, the near and far scores should be affected differentially, for the added rotation should be relatively more favorable (or unfavorable) for one line of sight than for the other. Examination of the data plotted in figure 4 reveals no apparent evidence of such differential effect.

In summary, then, an influence due to head or eye rotation could elevate or depress the prone and supine scores relative to the upright and inverted scores, but could neither change the overall hierarchy nor account for the differences we have ascribed to hydrostatic effects. If such an influence was present in this study, its effect was of little magnitude; otherwise, the near and far scores would not have had the same relative relationships for all four viewing conditions.

Thus, the effect of viewing condition on visual acuity is related to the particular combination of hydrostatic and acceleration effects involved, amounting to a maximum total decrement in a 1 G environment of approximately 15 percent.

That the total decrement was more than 15 percent on the average for far acuity and less than 15 percent for near acuity was pointed out previously. There is no evidence that this is more than a random difference since such small deviations in percent can occur easily by chance. Thus, we cannot say that near and far acuity are differentially affected by changes in viewing condition such as were employed in this study.

The generally superior resolution of targets at the far distance for all viewing conditions is another matter, however. The difference between near and far scores at each viewing condition is striking and is clearly significant. This could be due to sampling error (subjects with inherently better far acuity), but also may be a function of the use of checkerboard targets which somehow are "read" better at far distance than at near distance. The apparently superior resolution of checkerboard targets under far viewing conditions was noted independently in our previous study (ref. 4) and is supported by other evidence (ref. 2, pp. 13, 14).

Although we have spoken of "hydrostatic" and "pure -1 G" effects separately, the total acuity decrement is clearly a function of the general acceleration environment—for what we have referred to as the "hydrostatic effect" is itself a result of body acceleration. This leads naturally to generalized consideration of the effect of acceleration on visual acuity in terms of the deviation of the acceleration environment from normal. It will be recalled that White and Jorve (ref. 6) found increasing decrements in visual acuity as acceleration was increased from 1 G through several higher levels of positive G and that we (ref. 4) found a decrement at 0 G comparable to the White and Jorve decrement at 2 G's. This suggests the decremental effect is a function of the amount of change in acceleration but independent of the direction of change.

To test this possibility further, the data from the present study for the -1 G condition can be compared with the White and Jorve data for the 3 G condition—both conditions being 2 units of G removed from normal. The White and Jorve scores for the seated position at 1 G and 3 G's are converted to visual angles for comparison with scores for the upright (1 G) and inverted (-1 G) conditions, respectively, of this study.* See table III.

The mean of the differences between scores for the two environments of the White and Jorve study is 0.2 minute of visual angle, while for the present study it is 0.16 minute of visual angle. Thus, the White and Jorve subjects experienced the greater apparent loss. Interpretation of this must be tempered by consideration of the conditions of measurement. The 3 G measurements were made in the dynamic environment of the centrifuge where other, possibly deleterious, influences (noise, vibration) were present. These could account for part or all of the excess of the decrement at 3 G's over that in the static -1 G environment.

If we consider the generally better acuity of the White and Jorve subjects, their relatively greater loss at 3 G's is even more apparent. When the losses are converted to percent (relative to 1 G scores), the respective mean values are 22.9 and 15.5 percent. White and Jorve used a small sample of subjects thoroughly screened for good uncorrected vision. The difference between subject groups is reflected as the vertical difference between the two sets of curves in figure 5, in which the data of table III is shown graphically.

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*The comparison between "upright" scores from one study and "seated" scores from another study might be criticized on the technical point that the two conditions differ. To check on the practical validity of such a criticism, an independent comparison of seated versus upright acuity scores was made using 8 of the original 24 subjects of this study. The results (Appendix) indicate no significant difference between the two conditions.

TABLE III

MEANS OF ACUITY SCORES FROM WHITE AND JORVE STUDY AND FROM PRESENT STUDY
(in minutes of visual angle)

		White and Jorve			Present Study		
		1 G	3 G's	Difference	1 G	-1 G	Difference
Near	Left	0.88	1.09	0.21	1.17	1.32	0.15
	Right	0.94	1.14	0.20	1.21	1.33	0.12
	Binocular	0.91	1.04	0.13	1.16	1.28	0.12
Far	Left	0.85	1.00	0.15	1.02	1.20	0.18
	Right	0.89	1.22	0.33	0.94	1.16	0.22
	Binocular	0.86	1.06	0.20	0.91	1.08	0.17
Mean				0.20333			0.16167

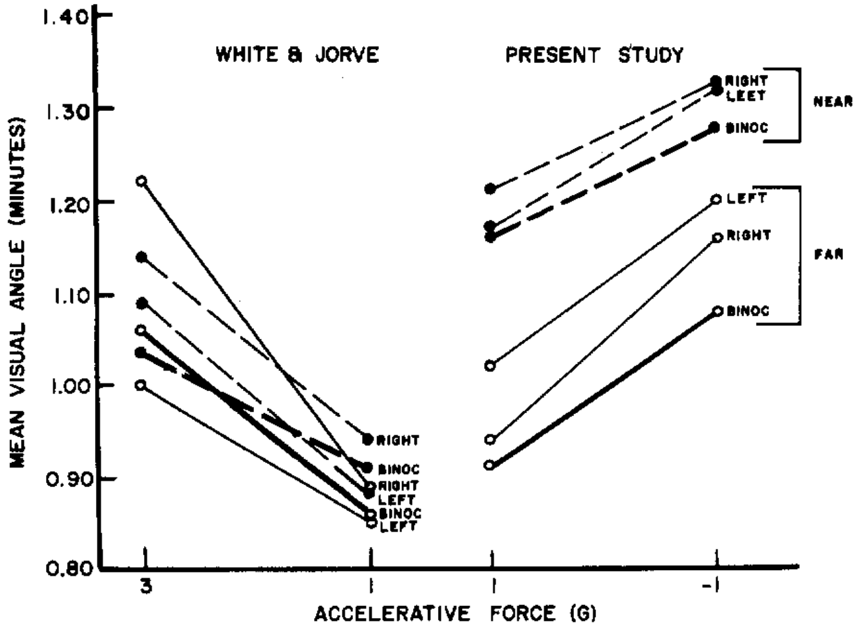

Figure 5. Comparison of Acuity Scores from Two Studies

In spite of the basic differences between subject groups and the relatively greater apparent loss of the White and Jorve subjects, the lines of figure 5 show strikingly similar changes in acuity resulting from 2 G changes in both directions from the normal condition at 1 G. This is taken as evidence in support of the hypothesis that visual acuity is reduced as a function of the amount by which the acceleration environment deviates from the normal 1 G environment independent of the direction of deviation.

If we plot the data of White and Jorve for the 2 G condition and our previous data for the 0 G condition on the appropriate ordinates of figure 5, we find good correspondence with deductions from the above hypothesis. That is, there is good agreement on the intermediate value of the decrements for acceleration environments which deviate from normal by only 1 G.

A further test of the hypothesis could be accomplished by measurement of visual acuity at increased values of negative G on a centrifuge. This would allow extension of acuity curves for extra units of acceleration in the direction opposite that studied by White and Jorve. As stated previously, it would be interesting to see if visual acuity functions plotted across the complete spectrum of tolerable acceleration would be "V" or "U" shapes symmetrical about low points at 1 G.

The results of this study have implications for space vehicle design proposals in which vehicle rotation is considered as a means of providing "gravity" (angular acceleration) and of obviating possible deleterious effects of long-term weightlessness. If the body of the astronaut is oriented so that he experiences the accelerative force from head to foot, the artificial gravity will be beneficial for visual acuity. According to our previous study, visual acuity increases as acceleration increases from 0 G to 1 G. However, if the astronaut reverses his body orientation, a not unexpected occurrence, considering requirements for intravehicular mobility, he will experience the reciprocal effect of negative acceleration. According to the present study, negative acceleration results in poorer visual acuity than does the 0 G condition (in defense against which the rotation is proposed). From at least one point of view, then, there are worse things than 0 G.

SUMMARY AND CONCLUSIONS

Twenty-four subjects were tested for left, right, and binocular acuity of near and far vision under each of four viewing conditions: (a) body upright, head upright, (b) body prone, head upright, (c) body supine, head inverted, and (d) body and head inverted. The first three conditions produced various combinations of acceleration and hydrostatic effects for control measurements, while the last condition effectively produced -1 G acceleration. Intercomparisons of scores from these viewing conditions form the basis for useful generalizations concerning the effects on visual acuity of various acceleration environments including 0 G.

The effects are related to the particular combination of hydrostatic and acceleration effects acting on the eye. Acuity is best with the body and head in normal upright position. A decrement of about 5 percent is found with the body prone and head upright, a condition in which there is intermediate hydrostatic deviation from the normal upright condition while acceleration at the eye is unchanged at 1 G. An additional 5 percent decrement is found with the body supine and head inverted, a condition in which the effect of the -1 G environment at the eye is added to the intermediate hydrostatic effect. Still another decrement of about 5 percent is found with both body and head inverted, the condition which "adds" the effect of the full hydrostatic deviation to the effect of -1 G at the eye to achieve the total effect of -1 G.

By comparison with acuity at 1 G, then, there is a decrement at -1 G of approximately 15 percent. This is comparable to the decrement found by other investigators at 3 G's.

A 0 G environment, being intermediate with respect to both hydrostatic deviation from normal and acceleration at the eye, should produce an intermediate decrement in acuity. This deduction agrees with results of a previous study in which a small but statistically significant decrement was found at 0 G, comparable to that found by other investigators at 2 G's.

Thus, 0 G and 2 G's, each 1 G-unit removed from the normal environment, produce comparable losses in acuity, while -1 G and 3 G's, each 2 G-units removed from normal, produce greater but still comparable losses. It appears that equal changes in either direction from the normal acceleration environment produce equal losses in visual acuity, with such losses increasing as a function of the amount of change.

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APPENDIX

VISUAL ACUITY UNDER SEATED vs STANDING CONDITIONS

Scores from this study were compared with scores from previous studies (refs. 4 and 6). In those studies, scores were obtained with subjects in the seated position. In this study, however, the comparable scores were obtained with subjects in the standing position. Since the objection might be raised that the difference in body position invalidates the comparison between the present and previous studies it is useful to know how scores from the two viewing positions compare when measurements are taken under carefully controlled conditions.

Eight of the original 24 subjects were retested in both the seated and standing posititions under laboratory conditions. The means of the resulting scores are presented in table IV along with the results of t-tests of differences between the two conditions of measurement.

TABLE IV

MEANS OF ACUITY SCORES
AND t-VALUES FROM TESTS BETWEEN PAIRED OBSERVATIONS
(in minutes of visual angle)

		Condition			
		Seated	Standing	t	(d.f. = 7)
Near	Left	1.02	0.99	1.22	> .10 (Not Significant)
	Right	1.05	1.01	2.02	> .05 (Not Significant)
	Binocular	1.06	1.04	0.88	> .10 (Not Significant)
Far	Left	0.94	0.96	-1.14	> .10 (Not Significant)
	Right	0.95	0.91	1.08	> .10 (Not Significant)
	Binocular	0.94	0.93	0.44	> .10 (Not Significant)

The differences between means for the two conditions are small. None is statistically significant. We thus conclude that visual acuity scores are not significantly changed in the standing position by comparison with the seated position.

The differences, while not significant, tend to favor the upright over the seated condition (five of the six comparisons are positive). This lends support to the belief expressed previously that the upright is the optimal viewing condition for visual acuity measurements.