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EFFECT OF MICROGRAVITY ON SEVERAL VISUAL FUNCTIONS DURING STS SHUTTLE MISSIONS

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ABSTRACT

Many astronauts and cosmonauts have commented on apparent changes in their vision while on-orbit. Comments have included statements of supposed improved distance acuity to decreased near vision capability. The purpose of this study was to assess not only changes in visual acuity, but expand the assessment to several other visual functions for a comprehensive battery of tests. Vision was assessed using an innovative device, the Visual Function Tester - Model 1 (VFT-1), which presents the tests at optical infinity and includes critical flicker fusion, stereopsis to 10 seconds-of-arc, visual acuity in small steps to 20/7.7, cyclophoria, lateral and vertical phoria, and retinal rivalry. Vision was assessed 2 times prelaunch at L-14 days and L-7 days, 3-4 times while on-orbit, at landing, and 2 times postlanding at L+3 days and L+7 days. There were 26 STS astronauts that participated, with data on 20 astronauts used for analysis. There was a typical wide variability between subjects in baseline visual performance for each parameter at the prelaunch sessions. There was a slight but statistically significant decrease in visual acuity while on-orbit that was not clinically significant. For stereopsis (ie. depth perception), there was a small improvement on-orbit that was not statistically significant. There were no changes during space flight for any of the other visual parameters tested. A few individuals showed apparent changes in acuity and stereopsis. The possibility exists that microgravity affects the visual system of some individuals differently, as with space adaptation syndrome. Repeat data on 2 astronauts showed good repeatability between the 2 flights. These results pertain to only short term space flight on the STS shuttle, and longer flights are necessary to determine if there is any relationship between mission duration and these visual functions.

INTRODUCTION

Many of the astronauts and cosmonauts have commented on apparent changes in their vision while on-orbit. Some comments by some astronauts[1] and cosmonauts[2] have included descriptions of earth features and objects that would suggest enhanced distance visual acuity. On the other hand, some cosmonaut observations suggest a slight loss in their visual discrimination during initial space flight[3]. In addition to distance vision changes, astronauts have mentioned a decreased near vision capability that either improved during spaceflight or did not recover to normal until return to earth [4].

In the late 1960's, Duntley et al.[5] used both ground targets and a hand-held device to assess visual acuity during Gemini V and VII and concluded there was no significant change in acuity. The Duntley device presented high and low contrast bar targets at optical infinity. The Soviets have tested acuity during a number of Voskhod and Soyuz flights, with the results summarized by Lazarev[6]: (1) slight decrease of 5 - 10% in high contrast acuity for 2 subjects on Voskhod flights, (2) 10% reduction in acuity for both high and low contrast targets for 3 subjects, but 20% increase in high contrast acuity for one subject on Soyuz-4 and 5, and (3) 18% drop in high contrast acuity and only 4% drop in low contrast acuity for one subject on Soyuz-9. However, the Soviet tests were conducted at a distance of about 30 cm, and therefore are for near vision. Since many cosmonauts are older in age, their findings may be complicated by any near vision problems.

These tests were performed at different optical distances and the results may have been affected by other factors, such as age and lighting conditions; and thus, are not comparable. The purpose of this study was to not only assess the effect of microgravity on distance visual acuity, but expand the assessment to several other visual functions under controlled conditions and over the length of space flight. The hand-held device used presented all targets at optical infinity and set light levels, and included high contrast acuity targets in small size increments, flicker fusion, stereopsis, phorias, and retinal rivalry, for a comprehensive battery of tests.

METHODS

Subjects

To date, 26 STS astronauts have participated since 1984 during 7 missions; and the mission number, number of subjects, and flight days on which data taken are listed in Table I. Unfortunately, 5 subjects from the same mission were able to complete only one pre-flight test close to launch and only one on-orbit test, and are not included in the analysis. Also one subject experiencing toric soft contact lens problems was eliminated, giving a total of 20 subjects for analysis. Visual correction for distance was worn, if necessary, when using the test device. Three astronauts wore contact lenses for all tests, including on-orbit. There was no statistical difference for these contact lens wearers from the other subjects and their data was included in the overall analysis. Two astronauts repeated the device on second missions, allowing at least limited repeat comparison.

Apparatus

Vision was assessed using a new innovative device, the Visual Function Tester - Model 1 (VFT-1) developed in our Laboratory by Drs Task and Genco. The VFT-1 has been previously described in detail[7], and an external schematic is shown in Figure 1. The battery of tests was chosen on the basis of detecting small changes in neurological or muscular balance. The visual parameters tested are presented at optical infinity and include critical flicker fusion, stereopsis (depth perception) to 10 seconds-of-arc, visual acuity in small steps to 20/7.7, cyclophoria, lateral and vertical phoria, and retinal rivalry (ocular dominance). The unit is self-powered (battery), and uses microelectronic circuitry and LED light bar modules to illuminate the test patches within the device.

Procedure

A pre-mission briefing and instrument familiarization session was conducted 1-2 months before the mission. Vision was assessed 2 times pre-flight at 14 days (L-14) and 7 days (L-7) before launch. While on-orbit data taking occurred 3-4 times; after wake-up and daily when possible, but were spread out on some missions. Post-flight, the VFT-1 was performed as part of the medical examination conducted about 2 hours after landing and again 3 days (L+3) and 7 days (L+7) after landing. All pre-flight and post-flight tests were performed with one of the experimenters in attendance.

Data Analysis

The data was analyzed by calculating the difference between the mean of the two pre-flight sessions (taken as baseline) and each subsequent measurement for each individual. Not all individuals performed the tests at the same mission elasped time on-orbit. There was also a slight non-normality due to the nature of some tests and, given the reasonably large number of subjects, nonparametric analysis (Wilcoxon Signed-Rank) was used to test for statistical significance.

Table I.

VFT-1 HISTORY OF SPACE-FLIGHT

MISSION	(DATE)	NO. SUBJECTS	DATA DAYS
STS-41D	(AUG 84)	2	1, 2, 4, 6
STS-41G	(OCT 84)	4	2, 5, 8
STS-51C	(JAN 85)	5	2
STS-51J	(OCT 85)	4	2, 3, 4
STS-33	(NOV 89)	5	1, 2, 3, 4
STS-36	(FEB 90)	5	2, 3, 4, 5
STS-38	(NOV 90)	3	2, 3, 4

Visual Function Tester No. 1

CONFIGURATION

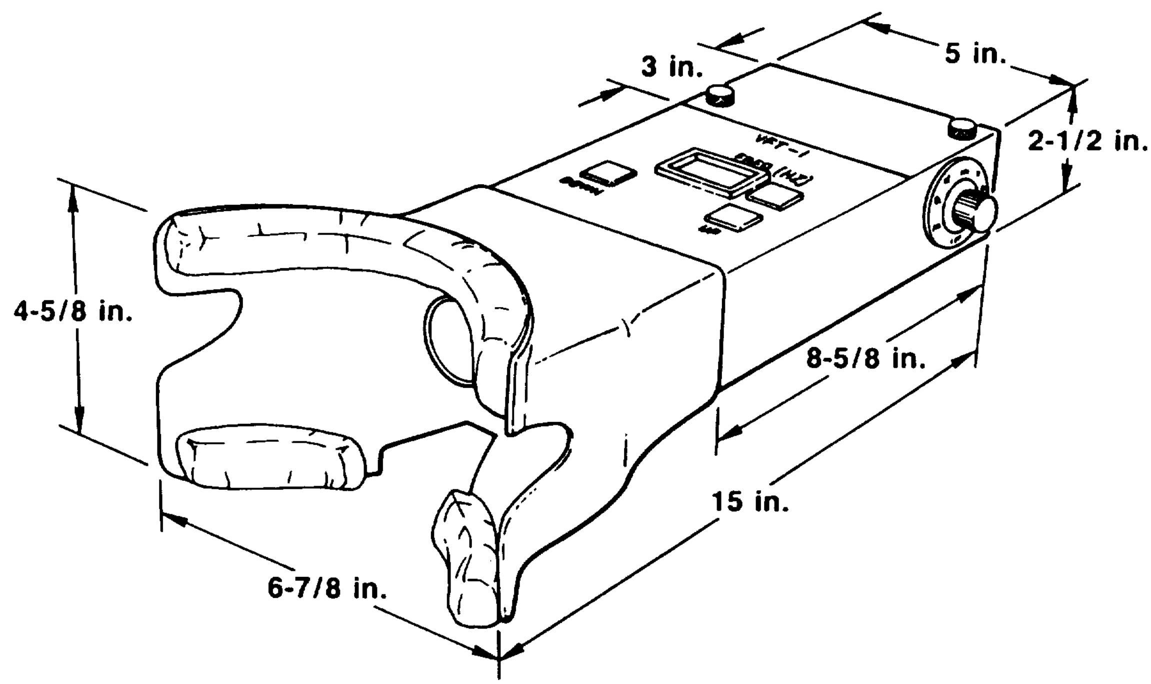

Figure 1. VFT-1 external view.

RESULTS

The group data for visual acuity, stereopsis, lateral and vertical phoria, cyclophoria, and critical flicker fusion is shown in Figure 2. The corresponding data days are: L-14 days is Pre-Flight 1, L-7 days is Pre-Flight 2, on-orbit data is at hours of mission elapsed time (MET), Landing is Post Flight 1, L+3 days is Post Flight 2, and L+7 days is Post Flight 3. The size of the dots represents the number of subjects with the same performance. It should be remembered that the subjects performed the tests a different number of times and at different MET on-orbit. The retinal rivalry data was obtained as the number of pattern reversals in a timed interval for some subjects and by subjective assessment on other subjects, and is not shown.

The group data show the normal wide variability between subjects in baseline visual performance for each parameter at the pre-flight sessions, as is characteristic of psychophysical data. Any apparent trend in the on-orbit data seen in the figures may not be actual, since less subjects performed the tests at the longer MET. The data was analyzed by calculating the difference between the mean of the two pre-flight sessions (taken as baseline) and each subsequent measurement for each subject. As seen in Figure 3, there was no apparent trend in the difference from the pre-flight mean for both on-orbit and post-flight individual data for lateral and vertical phoria, cyclophoria, and critical flicker fusion. Statistical analysis also showed no significant difference. There was also no difference in these comparisons for retinal rivalry.

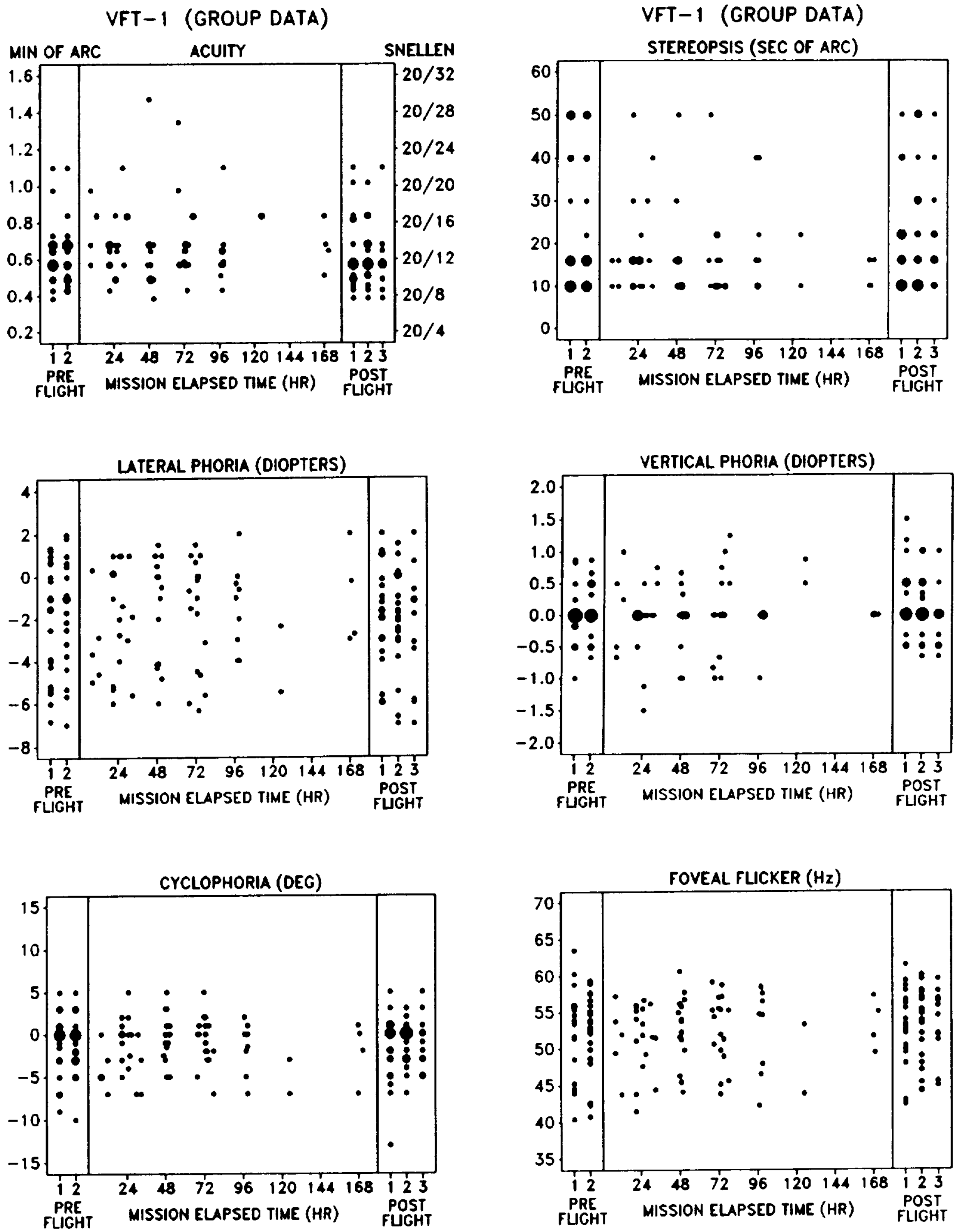

Figure 2. Group data on six vision tests for 20 astronauts. Size of the dots represents the number of subjects with the same performance.

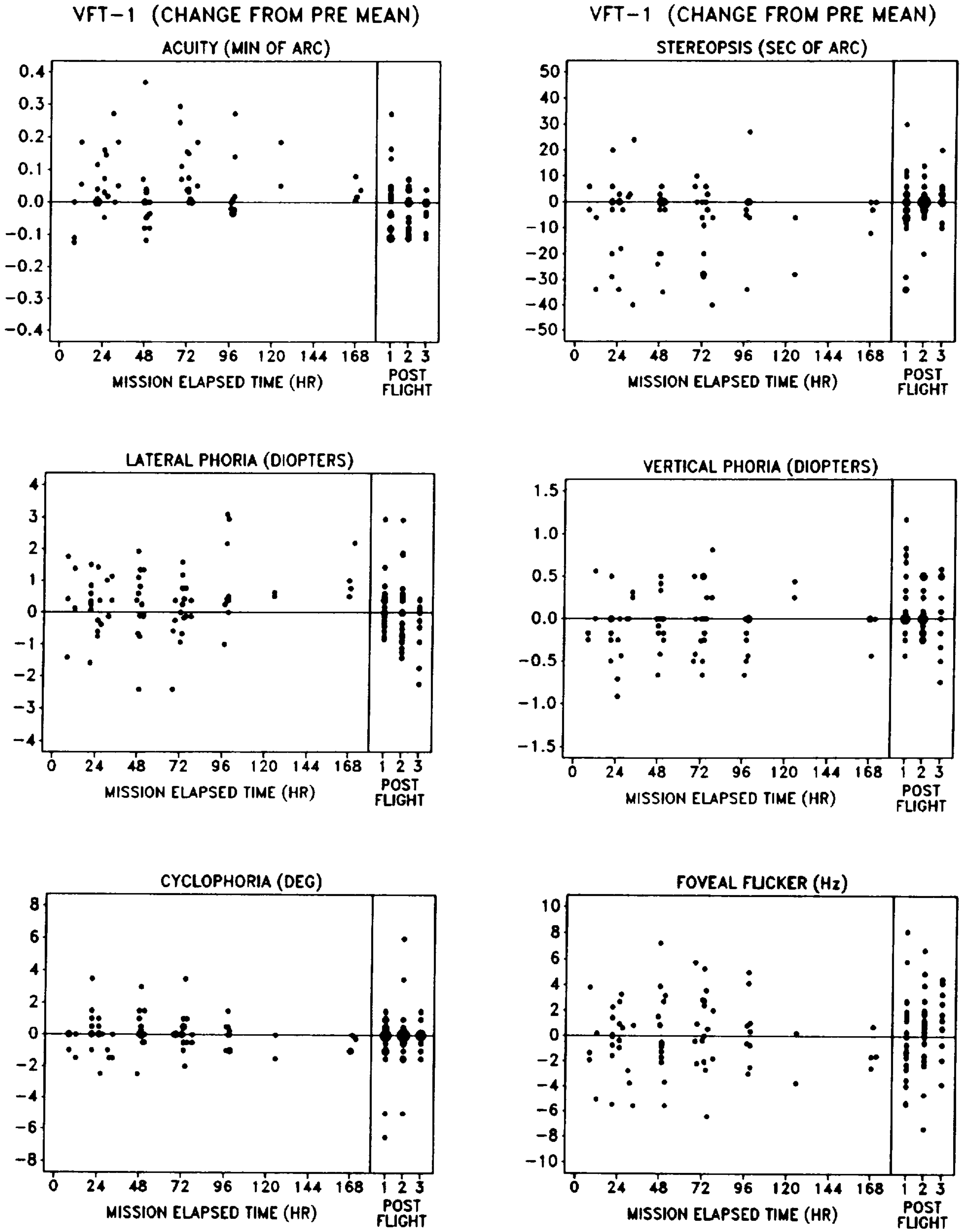

Figure 3. Difference between mean of two pre-flight sessions (baseline) and each subsequent measurement on six vision tests for each of 20 astronauts.

The mean pre-flight (baseline) and mean on-orbit change from pre-flight for the six vision tests is given in Table 2. As a group, the visual acuity was excellent at 20/12.5 and the other visual parameters were within normal limits, although slightly poorer for stereopsis.

Stereopsis Change

The difference in stereopsis from the pre-flight mean of the on-orbit and post-flight individual data is also shown in Figure 3. There is a slight trend towards smaller seconds-of-arc stereopsis (i.e. improved stereopsis) while on-orbit, that is no longer appparent post-flight at landing or the later data sessions.

The mean change in stereopsis from the baseline at the subject's first data take on-orbit was -5.0 arc sec and was the same (p=0.99), also at -5.0 arc sec, at the subject's last data take on-orbit. The data was therefore combined to obtain group change on-orbit. The mean group change in stereopsis was -4.9 arc sec from baseline while on-orbit, which was nearly significant (p=0.07). The mean change in stereopsis from baseline was only -0.8 arc sec at landing and +1.1 arc sec by the second post flight (L+3 days) session.

Visual Acuity Change

The difference in visual acuity from the pre-flight mean of the on-orbit and post-flight individual data is also shown in Figure 3. There is a definite trend toward larger minute-of-arc resolution (i.e. decreased acuity) while on-orbit, that is no longer apparent post-flight at landing or the later data sessions.

The mean change in visual acuity from baseline at the subject's first data take on-orbit was +0.04 min arc, but is not significant (p=0.13). At the subject's last data take on-orbit, the mean change in acuity from baseline was +0.07 min arc, and is statistically significant (p=0.001). Comparison of the on-orbit acuity data showed no significant difference (p=0.15) between the first and last data takes, and the data was combined to obtain the group change on-orbit. There was a significant (p=0.005) mean group change in acuity of +0.06 min arc from baseline while on-orbit. However, this corresponds to only a Snellen acuity change of from 20/12.2 at baseline to 20/13.4 on-orbit, which is not operationally significant. There was no change in acuity from baseline at landing (p=0.90) and only slight differences for the other post flight means.

Table II.

VFT-1 GROUP DATA

	MEAN PRE-FLIGHT	MEAN CHANGE
VISUAL ACUITY	0.610 min arc (20/12.2)	+0.06 min arc (to 20/13.4)
STEREOPSIS	19.8 arc sec	-4.9 arc sec
LATERAL PHORIA	-2.08 $^{\Delta}$ (ESO)	+0.36 $^{\Delta}$
VERTICAL PHORIA	0.04 $^{\Delta}$	-0.07 $^{\Delta}$
CYCLOPHORIA	-1.14 ^{o} (ENCYCLO)	-0.02 ^{o}
FOVEAL FLICKER	52.43 Hz	-0.06 Hz

Percent (%) Acuity Change

The percent (%) difference from the pre-flight mean of the on-orbit and post-flight individual data for visual acuity is shown in Figure 4. Most of the data points on-orbit show a positive percent change in min-of-arc letter size, corresponding to a decrease in visual acuity. Single data points on-orbit ranged from a 40% loss in acuity to a 20% improvement in acuity. The mean percent change (loss) in acuity from baseline while on-orbit was 7.5%.

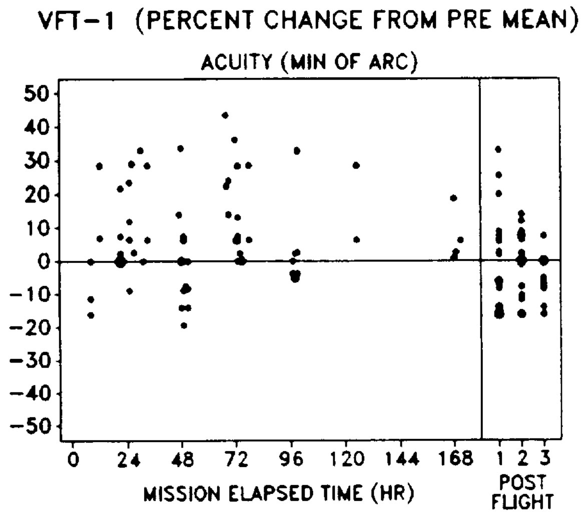

Figure 4. Percent (%) change in visual acuity from the pre-flight mean for 20 astronauts.

Repeat Subjects

There were two astronauts that participated in the VFT-1 study on second missions, allowing for a repeatability comparison of their data. In general, these subjects confirmed their initial results, as seen in Figure 5 for visual acuity and stereopsis. The filled symbols are for the first mission, while the empty symbols are for the second mission, with circles for one subject and triangles the other. As seen for visual acuity, there were slight differences in baseline visual performance over the years between flights for all parameters tested, with similar change on-orbit.

Of particular interest in the repeat subjects was the stereopsis data, since both subjects had shown a marked improvement in stereopsis on-orbit during their first mission. As seen in Figure 5, the pre-flight stereopsis was very similar (although poor) prior to both missions, and although one on-orbit data point for each subject varied, the overall results indicate an improvement in stereopsis occurred again on the second mission.

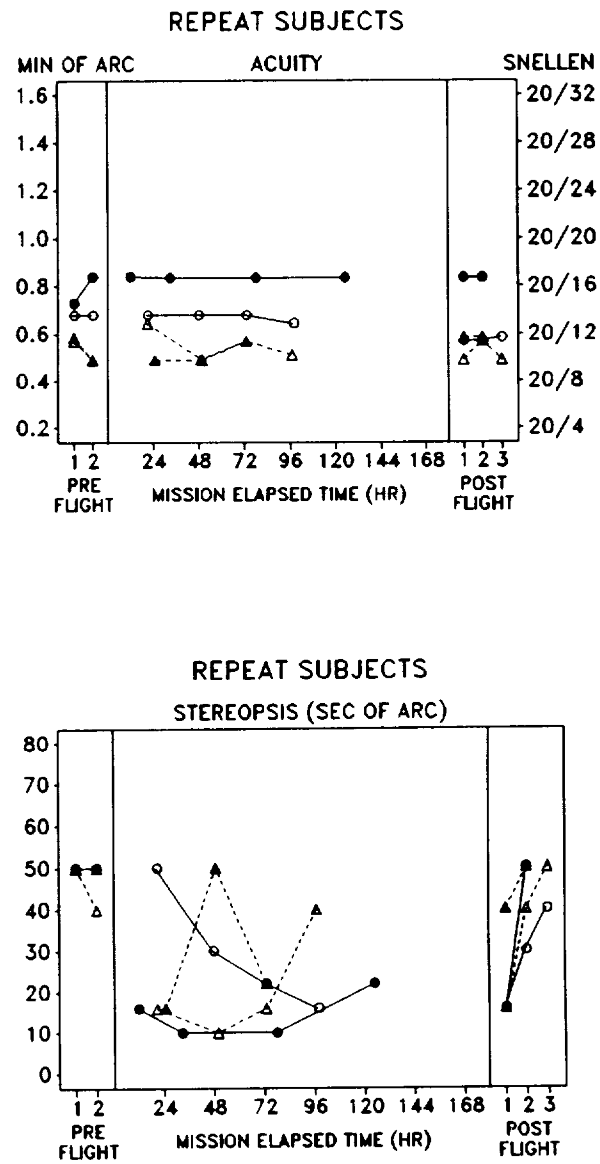

Figure 5. Individual visual acuity and stereopsis data of two astronauts on first (filled symbols) and second (empty symbols) missions.

DISCUSSION

There were no group changes on-orbit for lateral and vertical phorias, cyclophoria, critical flicker fusion, and retinal rivalry. There was a definite trend toward loss of acuity while on-orbit that was statistically significant. However, the mean visual acuity loss was only 0.06 min-of-arc. This corresponds to only a slight change in Snellen acuity from 20/12.2 at baseline to 20/13.4 on orbit. This degree of acuity loss is of little clinical significance, as it represents less than one line of acuity on a standard chart.

The acuity change also equates to a mean loss of 7.5/corresponds well to that reported by the Soviets for their high contrast targets, although their tests appear to have been conducted at a near test distance. There was also a wide range in single data points on-orbit, ranging from a 40% loss to a 20% improvement in acuity, and some subjects varied by as much as 20% on-orbit. This could explain the similar Soviet variability in response between cosmonauts, particularly if the data was taken only one time on-orbit.

Our results do not entirely agree with those of Duntley et al.[7] They found no statistically significant change in visual acuity on-orbit, while we did; while both changes were very small. This may be due to the small increments between letter sizes in our study (e.g. 20/15, 20/14, etc.), allowing for a finer measurement than the typical Snellen acuity line differences.

There was also a slight trend for stereopsis to improve while on-orbit, although mainly for a few subjects and not statistically significant. This improvement was most noticeable for subjects that had large seconds-of-arc stereopsis at preflight. In particular, two subjects had pre-flight stereopsis of about 50 arc sec that improved to 20 or 10 arc sec (the smallest stereo target) while on-orbit, and returned back to baseline post flight. For depth perception to improve, then there would have to be less difference between some aspect of the eyes (e.g. refractive error or eye muscle control) such that the eyes coordinated better. However, the data obtained do not allow the mechanism for the improvement to be determined; although the eye muscle control did not appear to change.

There were two astronauts that participated in the VFT-1 study on second missions, allowing for a repeatability comparison of their data. In general, these subjects confirmed their initial results. Of particular interest was the stereopsis data, since both subjects had shown a marked improvement in stereopsis on their first mission (as noted above). Although one on-orbit stereopsis data point for each subject varied, the overall results indicate an improvement in stereopsis occurred again on the second mission. For the other visual parameters, the pre-flight data varied between missions, but the change from baseline on-orbit remained very similar. It would appear that the data obtained with the VFT-1 device has validity, since repeat data overall confirmed earlier findings.

These results are for the short duration spaceflight of STS missions. It would be of interest to evaluate visual performance over longer periods on-orbit. Using a device such the VFT to present test patterns at set light levels and optical distance would allow an accurate determination of the effect of long-term microgravity on a number of visual parameters.

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DISCLAIMER

The views expressed in this article are those of the authors and do not reflect the official policy or position of the Department of Defense of the U.S. Government.

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