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VISION IN SPACE TRAVEL

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V. Popov

N. Boyko

Aviatsiya i Kosmonautika (Aviation and Astronautics),
No. 3, 73-76 (1967)

Translated from the Russian

August 1967

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VISION IN SPACE TRAVEL

by

Colonel V. Popov*
Major N. Boyko*

Since pilots and astronauts use their organs of vision to obtain basic information about the performance of spaceship systems and outside environments, the authors discuss the reliability of such information particularly under conditions of supersonic or space flight. Vision-sharpness tests are discussed. For example, it was found that the level of functional stability of chromatic vision is substantially affected by a series of conditions such as color, adaptation, simultaneous and subsequent contrast, comparison features, etc. Under space-travel conditions definite changes are experienced by the functional abilities of a vision analyzer.

Both aircraft pilots and astronauts use their organs of vision to obtain the basic information about the performance of the spaceship-systems and about the outside environments. How perfect, however, are these organs and how reliable is the information received with their aid under conditions of supersonic or space flight?

With each year, these questions attract an ever growing attention of the specialists in aviation, space travel medicine, and in psychology.

The American psychologist, Paul M. Fitts, for example, claims that the vision-analyzer is responsible for three-fourths of all errors made by pilots during a flight. As a matter of fact, a spaceship is like a modern supersonic aircraft. And this, naturally, is a reason for caution.

The design of manually controlled systems of the existing and prospective spaceships, the contact with objects in space, and the landing on other planets are, as a rule, based on men's ability to detect light-signals amid certain backgrounds and to identify different types of visible shapes. The importance of the level of the functional abilities of the vision of astronauts is, therefore, obvious. It is not by mere accident that many articles in our and in foreign medical literature are devoted to this question.

Prior to the flights in space, assumptions were made that the absence of gravity might cause a deformation of the eyeball and change the functional

*Medical Corps.

abilities of the vision-analyzer. It was expected that the moving apparatus, the eye, would lose to some extent the coordination of motions which it acquired during its lifetime on earth and, as a result, the function of vision would be disrupted: it would impair the vision in depth, it would disrupt the processes of accommodation and convergence, etc.

All of these had to be checked and, if possible, they had to be checked before man's travel in space. Experiments were already made with aircraft flying along a Kepler curve when, although for a short duration, it was possible to obtain a state of weightlessness.

American specialists have noted that the sharpness of vision during such flights was reduced by an average of six percent. Interesting data were also obtained by Soviet medics. For example, L. A. Kitayev-Smyk observed in cases of weightlessness an increase, diffuseness, and bending of visible objects. When investigating the perception of colors, he found an increased brightness of the colors, particularly that of yellow. Certain operators had observed a violet halo around luminous objects.

Investigations had shown that, with the arrival of weightlessness, the vision-sharpness was first reduced and, with this state continued, it was restored for certain persons and even exceeded the original level.

However, the results of the investigations of flights along a Kepler curve did not provide, of course, a complete picture because, during the 35-40 seconds, the organism was unable to adjust itself to the conditions of weightlessness. The obtained data could be considered as representing only certain transient values of the investigated function.

Therefore, as soon as it became possible, investigations were made in environments common to space travel. The program of investigation on the spaceship "Voskhod-2" included the study of the resolving capacity of the vision-analyzer of astronauts. The vision-sharpness was checked with the aid of a set of line-targets (for lens resolution tests) pasted into the log book. These had to be viewed from a distance of 300 mm.

A series of correlated tests were performed to disclose the relationship between the magnitude of vision-sharpness usually determined from the tables of Sivtsev and by the method used in our experiments. The vision-sharpness of the tested persons was first determined from the Sivtsev tables (Landol't rings) and later by the lined targets. The obtained results show a good agreement between these two methods.

The resolving capacity of the astronauts' vision-analyzer was determined by our method by the laboratory investigations made before the flight. Both the main and the duplicate crew of "Voskhod-2" were included in the investigation. The investigation was also carried out during the training on a training ship in accordance with the program devised for the flight. These data were needed for comparison with the flight-data.

The following was disclosed by this comparison:

TABLE I

Name of Astronaut	Sharpness of Vision Laboratory Test (5 measurements)	On Training Ship (2 measurements)	In Flight (2 measurements)
A. A. Leonov	1.7	1.4	1.64
P. I. Belyaev	1.7	-	1.34

The vision-sharpness of the astronauts was determined during 5-6 convolutions. Two measurements were taken for each test.

The obtained results indicate comparatively small changes in the resolving capacity of the vision-analyzer. Compared with the data obtained under laboratory conditions, the impaired vision-sharpness of P. I. Belyaev can be explained as resulting from the character of the illumination on the spaceship. The following conclusion can be made: the vision-sharpness does not undergo considerable changes during a one-day space flight.

Also tested during the flights of the "Voskhod" spaceships was the vision-efficiency of the astronauts.

The operational efficiency can be determined with the aid of the same test-tables and the lined targets. For this, the operator is advised to find an element of the target in which he is able to count the number of lines by holding the target at a distance of 300 mm. For the investigation, such a voluntary selection of a target-element eliminated the effect of the vision-sharpness on the results of the test, because the tested person operated in any case with his above-threshold value, i.e., a value higher than under normal and usual conditions.

This method was also first tested by laboratory experiments and the obtained results were compared with the flight data.

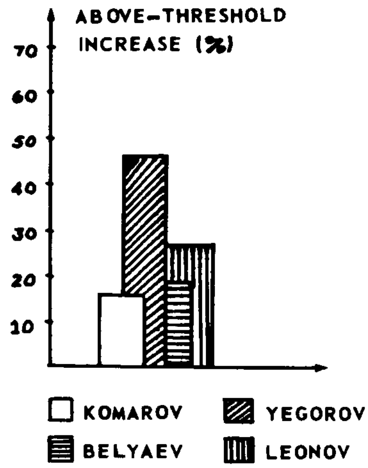

FIGURE 1. ABOVE-THRESHOLD INCREASE IN VISION-SHARPNESS OF ASTRONAUTS TESTED BY THE METHOD OF STUDYING THE OPERATIONAL VISION-EFFICIENCY

The above-threshold increase in vision-sharpness of the astronauts is shown in Figure 1.

The vision-efficiency of the crew of "Voskhod-2" is shown in Table II.

This table shows that the operational vision-efficiency is reduced considerably in a spaceship. This is evidently due to the fact that, in the presence of weightlessness, the overall coordination of movements is not only disrupted but there is also a certain loss in the coordination by a group of eye-moving muscles. Their effort under the new conditions to change the point on which the vision is fixed becomes excessive and, as a result, the required point appears as if it were "skipped." The need is for an eye tuned differently than before; in this case, however, it is difficult to obtain, because the new impulse which follows at the expiration of 0.01 second occurs during the period of the refractory phase and is skipped. This phenomenon, however, is not observed when larger parts are counted, because the frequency of the impulses is drastically reduced when the angle of resolutions increases.

TABLE II

Name of Astronauts	Conditions of Observation								
	Laboratory Tests			On Training Spaceship			In Flight		
	Reliability	Duration of Test (seconds)	Vision-Sharpness	Reliability	Duration of Test (seconds)	Vision-Sharpness	Reliability	Duration of Test (seconds)	Vision-Sharpness
A. A. Leonov	100%	36	0.95	88%	60	1.1	75 %	90	1.2
P. I. Belyaev	100%	43	1.17	-	-	-	80.8%	-	1.06

Also obtained was the data on the perception of colors of objects during space travel. Our aim was to investigate the perception of color of objects located inside the spaceship, for which purpose we used a special table. This table contained six strips of different colors located alongside black-white stepped wedges. It is known that all colors with weakening brightness become close to that of black. Consequently, the brightness of any color compared with that of the extent of a black-white wedge can serve as an objective indicator of its brightness. Three basic colors: red, green, and blue and three of their complementary colors -- azure, purple, and yellow have been selected for the investigation. The astronaut's task was to find during the flight a black-white field of a wedge having the same brightness as each of the tested colors.

The black-white wedge made it possible to measure the color-brightness of objects for color changed ten times. The average error of a single determination of the color's brightness with the aid of this table was equal to 15 to 30 percent. A statistical processing of the repeated measurements made during the flight made it possible to reduce the error to 5 to 6 percent.

The comparison made in daylight between the reference, or background, and the flight-results of the investigations made it possible to disclose the differential changes in perception of colors of objects. The level of functional stability of chromatic vision is substantially affected by a series of conditions, such as color adaptation, simultaneous and subsequent contrast, comparison features, etc. These had to be taken into account to disclose only the effect of weightlessness on the investigated function of vision. For this was derived the root-mean-square error of a single equalization of the brightnesses of the colored and black-white fields. Measurements taken at different times and with different color-tables had shown that this value for the used colors is equal ±7.8 percent.

The flight of "Voskhod-2" made it possible to establish a noticeable reduction in subjective brightness of the colors examined by astronauts. The average reduction in brightness of all exhibited colors was equal to 26.1 percent for P. I. Belyaev and to 25 percent for A. A. Leonov. The largest deviations were observed in determining the brightnesses of purple, azure, and green colors; the least deviation was in case of red color (Fig. 2). The reduced brightness of the remaining colors did not exceed 10 percent. In none of the cases was there noted an increase in brightness of the exhibited colors. The reason for such a large reduction in brightness of certain colors in cases of weightlessness remains unknown and additional and more refined investigations are needed to find it.

The astronauts' reports about the visual observation of the earth's surface and objects in space are of unquestionable importance from the standpoint of disclosing the effect of prolonged weightlessness on the resolving capacity and other functions of vision. These reports also indicate a process of comprehending the obtained information.

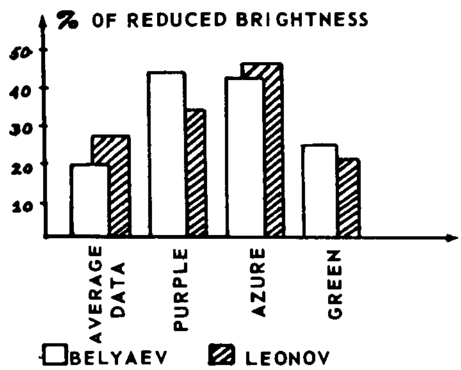

FIGURE 2. PERCEPTION CHARACTERISTICS OF COLORS OF OBJECTS DURING SPACE TRAVEL

Table III shows an analysis of the materials describing the observations of the earth's surface and the calculated vision-sharpness of astronauts.

From the table it is apparent that sharpness of vision exceeds the average under the conditions of orbital flight, but this relates only to objects with a linear extension (roads, inversion traces, and the like). But in conformity with this, sharpness of vision has also been raised under conditions on earth to an even greater extent than that shown on the table. S. V. Kravkov wrote about this in part back in 1936.

TABLE III

Observed Objects	Approximate Size of Objects, in Angular Minutes	Vision-Sharpness
	Minimum	Maximum
Rivers, such as the Amazon, Volga, Nile	10-20	0.1-0.05
Large roads	0.2-0.5	5-2
Takeoff and landing strips	0.5-1.0	2-1
Cruising ships	0.3-1.5	3-0.7
Rolling ships	1-3	1-0.3
Inverse traces of aircraft	0.2-0.4	5-2.5
Bathing beach strips (Caucasus)	0.3-0.5	3-2

It was reported in the press that the American astronaut Cooper during his flight had seen craters in Tibet and automobiles on the roads of the Southwest, while the astronauts Cernan and Stafford were able to observe the shape of aircraft on the takeoff and landing strips.

Is this due to the exceptional vision-sharpness of the astronauts, or is it the result of the effect of the conditions of the flight? The ability to identify the

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types of the aircraft may be due not only to the high resolution capacity, which is several times higher with certain persons, but it may also be due to the knowledge of the types of planes located at a given base.

Our investigations show that, under space-travel conditions, definite changes are experienced by the functional abilities of a vision-analyzer. Although the accumulated information is still inadequate and further study is needed to answer certain questions, yet, even now, it is possible to claim that the peculiar behavior of human vision in space must be also taken into consideration. This pertains to both the specialists designing the instruments and the indicating facilities and also to people engaged in training astronauts for flights in space.

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