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ARCTIC AEROMEDICAL Laboratory

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PROJECT NUMBER 22-1201-0001
REPORT NUMBER 1

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THE EFFECT OF PROLONGED ARCTIC FLIGHT ON NIGHT VISUAL ACUITY

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ARCTIC AEROMEDICAL LABORATORY
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PRECIS

OBJECT:

To investigate the effects of prolonged arctic flights on night visual acuity during subsequent ground operations.

SUMMARY AND CONCLUSIONS:

The night visual acuity of 92 crew members of 9 WB-29 crews has been measured with the Kodak night vision tester immediately following completion of prolonged weather reconnaissance flights in the arctic and subarctic. Each individual post-flight test score has been compared with that attained by the same subject following a recovery period of at least 36 hours. The study has encompassed a period of 13 months and the crews have been exposed to extremes of lighting ranging from the arctic night in January to continuous sunlight on pack ice and cloud undercast in July. Observers were present on five of the missions and vitamin A intake has been recorded as a part of a nutritional survey reported in detail elsewhere. The results of this study have led to the following conclusions:

1. Light exposure during prolonged polar flights at high altitude is not sufficiently intense at any season of the year to produce significant effects on subsequent night visual acuity.

2. There is a distinct possibility that a partial acclimatization to altitude sufficient to bring about improvement in night visual acuity may occur during an exposure of 15 to 18 hours to a pressure altitude of 8,000 to 10,000 feet.

3. The physiological and psychological stresses attendant upon prolonged night flights may bring about a significant and perhaps serious decrease in night visual acuity following extended missions.

4. Since these stresses are independant of exposure to high light intensities, they may be expected to operate at all latitudes.

RECOMMENDATIONS:

It is recommended that short-term acclimatization tests be conducted in a decompression chamber. Subjects with known night visual acuity scores should be held at a pressure altitude of at least 8,000 feet under normal lighting conditions for a continuous period of at least 18 hours. Following

descent and dark adaptation they should be retested to determine whether improvement in ground level night visual acuity has resulted. The results should be treated statistically on the basis of changes in individual scores rather than change in group mean scores. Particular care should be taken to insure that illumination within the chamber neither exceeds nor falls short of the level to which the subjects are normally exposed. Positive results would indicate the need for a re-evaluation of directives prescribing the use of oxygen during night flights.

THE EFFECT OF PROLONGED ARCTIC FLIGHT ON NIGHT VISUAL ACUITY

INTRODUCTION

One of the major environmental factors peculiar to arctic operations is the extreme seasonal variation in length of day. This results in prolonged periods of high light intensity during the summer. In modern, long-range air operations it is commonplace for men to take off in darkness from a subarctic or temperate zone airfield, fly long hours over brilliantly lighted snow, pack ice and cloud banks and land in complete darkness on the other side of the world. Since it is known from the work of Hecht et al. in 1945 (1) that exposures to high light intensities may have serious, cumulative and prolonged effects on subsequent night visual thresholds, we thought it advisable to investigate the effects of extended arctic flights on the night visual acuity of bomber crews.

It may be said at the outset that we have found that the effect of light exposure under actual operating conditions may be ignored. Other factors which we are not in a position to evaluate do affect the night visual acuity of aircrew members. Strangely enough, statistical analysis shows that the effect is not always adverse.

BACKGROUND

The 58th Strategic Reconnaissance Squadron, stationed at Eielson Air Force Base, flies two types of weather reconnaissance missions on alternate days. The Loon Dog is flown westward over the Bering Sea and the Ptarmigan is flown northward to the Pole. These missions are flown in WB-29's at an altitude which varies somewhat but which usually requires pressurization to between 8,000 and 9,000 feet cabin altitude. The missions require between 15 and 18 hours. The crews are more or less stable in composition, although substitutions are occasionally made and the individual crew members have different rotation dates. Crews normally consist of two pilots, weather observer, flight engineer, radar operator, two navigators, two scanners, (one of whom is the crew chief and the other the dropsonde operator) and two radio operators. Occasionally there are differences. For example, one of the pilots may be a qualified weather observer in which case the crew will have one less member. Aircraft assignments are for one mission only and are made in the order in which the planes become available.

Morale is generally high, and there is much group and individual pride in accomplishment. One engineer recently celebrated his 50th flight over the pole with considerable attention by the press and radio and similar achievements on the part of crews, the squadron, individual planes and even engines are duly noted. The squadron has an enviable safety record. Maintenance, preflighting and briefing are extremely thorough and the organization is continually seeking improvements in navigational procedure, safety procedures, emergency equipment, etc. The men feel that their work is important and appreciated and they know that no stone would be left unturned in the effort to find them should a crash landing be necessary. The whole atmosphere is one of quiet efficiency, confidence and pride. We were repeatedly amazed at the lengths to which the organization would go to support our study. It is not possible to imagine a more co-operative and interested spirit than that in which time, space, facilities and personnel were made available for our project.

MEASUREMENTS AND OBSERVATIONS

Nine crews, comprising 92 individuals, were tested with the Kodak Night Vision Tester, Model 2, before and after the flights. The tests may be classified as follows:

1. First Preflight Test. This was given before the flight and after thorough instruction in the mechanics of the test. In 23 cases it was the only control test given.

2. Second Preflight Test. This was given the day following the first preflight test to 26 crew members. Since there was no significant difference in the scores of these men on the two preflight tests (see Table I), the use of this second test was discontinued. It seems safe to assume that learning and increased familiarity with the procedure does not affect the scores in repeated tests.

3. "Recovered" Test. On 3 missions involving 33 crew members, the crews already preflight tested had to be replaced by new crews at the last minute. In these cases it was necessary to administer the control test after a suitable recovery period, i. e., at least 36 hours following the mission and postflight test. A priori, if learning can be ruled out as a factor affecting scores on successive tests, there is no reason to distinguish between preflight and recovered tests since a recovered test for one mission could serve in many cases as a preflight test for the succeeding mission. Actually, in one case involving 10 crew members, a crew was given one preflight and one "recovered" test. It should be noted that these control tests were the first and third administered to these men, yet the mean difference in scores was only 0.8 ± 2.0. This difference is not significant, and for convenience in further calculations, recovered test data on this crew were combined with data from the second preflight test of another crew (December, Ptarmigan).

4. Postflight Test. This was given in every case immediately upon completion of the mission.

In the earlier part of the study, testing was carried out in a completely darkened, mobile laboratory trailer. The later tests were administered in the carefully blacked-out squadron war room. Dark adaptation consisted of a 40-minute period with the red goggles followed by 10 minutes in complete darkness. The distance from the screen of the tester to the faces of the subjects was 20 feet and the tester lamp was adjusted to draw exactly 4 amperes. The slight noises emitted by the tester were masked by the sound of an electric fan. Subjects were carefully instructed in the mechanics of the test and the very few who used corrective lenses were asked to keep them on during the test.

Sample data on the two crews tested in July are presented in Table I and a summary of all test data, including that presented in Table I, is given in Table II. The maximum attainable score is 40. It will be observed that the spread between the highest and lowest scores on any one test is very large (Table I). For this reason and because the number of individuals involved is small, changes in the mean score of the entire group from test to test are not very illuminating. Small but significant changes in the score of a given individual are apt to be covered up by the much larger differences between different men. Therefore, although mean scores are reported in Table II, the statistical treatment was directed toward the analysis of changes in individual scores rather than changes in mean scores. Thus, instead of comparing the averages of the raw scores achieved by a given crew on successive tests, the averages of the differences in the successive scores of individuals have been compared. The standard error of the mean differences was computed in the usual manner.

It is obvious that where the standard error is almost as large as the mean change in scores, the change is without significance. On the other

TABLE I

Individual Night Visual Acuity Scores * - July Ptarmigan Crews

	Preflight No. 1.	Preflight No. 2.	Change (Learning)	Mean Preflight	Postflight	Change
Crew No. 1.	31	30	-1	30.5	39	+8.5
	35	35	0	35.0	37	+2.0
	26	21	-5	23.5	28	+4.5
	26	25	-1	25.5	31	+5.5
	32	36	+4	34.0	38	+4.0
	22	18	-4	20.0	14	-6.0
	20	17	-3	18.5	23	+4.5
	32	34	+2	33.0	38	+5.0
	10	10	0	10.0	19	+9.0
	34	36	+2	35.0	35	0.0
Crew No. 2.	36	33	-3	34.5	37	+2.5
	28	33	+5	30.5	35	+4.5
	37	31	-6	34.0	39	+5.0
	28	22	-6	25.0	28	+3.0
	23	27	+4	25.0	32	+7.0
	17	18	+1	17.5	32	+14.5
	29	28	-1	28.5	34	+5.5
	27	28	+1	27.5	38	+10.5
Mean	27.4	26.8	+0.72 ± 0.79**	27.1	32.1	+4.97 ± 1.00**

* Maximum Possible Score 40

** Standard Error (See Table II)

TABLE II

Summary of Results of Night Visual Acuity Tests

LOON DOG MISSIONS	NO. OF INDIVIDUALS	GROUP MEAN SCORES			MEAN CHANGE *	REMARI **
		PREFLIGHT TEST	"RECOVERED" TEST	POSTFLIGHT TEST		
November	12	32.0	--	32.8	+0.75±0.87	NS
January	9	--	29.1	26.2	-2.89±2.12	NS
PTARMIGAN MISSIONS						
November	13	--	26.9	21.1	-5.77±1.72	Sig
January	11	--	32.4	24.4	-8.00±1.23	Sig
May	11	28.9	--	30.5	+1.64±1.60	NS
July	18	27.4, 26.8	--	32.0	+4.97±1.00	Sig
December	18	26.5, 26.6***	--	28.2	+1.36±1.15	NS

* $M = \frac{\Sigma X}{N}$, where X = the change in the score of an individual;

$$S.E. = \frac{\sigma}{\sqrt{N}}; \quad \sigma = \sqrt{\frac{\Sigma X^2}{N} - M^2}$$

** NS = not significant;
Sig = Significant at or below the 1% level

*** In 10 of these cases, the second control test was actually a "recovered" tes
but since there was no significant difference between preflight and recovere
scores, all data on the second control test have been combined under "prefli

hand, where the standard error is only a small fraction of the change, the change is almost certainly a real one. Each change reported as significant in Table II is significant at or below the 1% level. In other words, there is less than one chance in 100 that it is due to random variation only.

After it had been determined that there was no significant difference between the scores achieved in successive control tests on the same crew, the results of these tests were combined to obtain the "normal" individual scores. Similarly, it was found possible to treat both crews tested in July as one group and both of the December crews as another, single group.

Each of the five Ptarmigan crews flying in May, July and December was accompanied by two observers from this laboratory. All crew members on these missions were under constant observation from the beginning of the preflight aircraft check to the completion of the postflight night vision test. The observers' notes constitute a running account of altitude, weather, lighting conditions at each crew position, composition and consumption of in-flight rations, activity and behavior of each crew member, etc. In most cases, one of the observers was an airman, the other an officer. Among the officer observers were pilots, doctors, physiologists, and a psychologist. Very friendly relations existed between crew members and observers at all times, particularly since the observers had had ample opportunity to become acquainted with the crew members before the flights. The observers as a group feel that their presence did not in any way alter the normal procedures of the missions and that the missions in which they participated were valid samples of the activities of the squadron.

Under normal conditions, the hardest working crew members are the navigators and the radio operators. The navigators work constantly throughout the flight with almost no opportunity to relax until landfall on the return trip. Moreover, theirs is probably the most crucial job and, depending on the individual, there may be considerable nervous strain evident. The radio operators work almost as steadily but without the strain of knowing that the fate of the mission and crew is entirely in their hands.

The rest of the crew members spend much of the time conversing, reading, dozing, eating, etc., in a very relaxed manner. Very little overt apprehension is evident in any of the crew members even under relatively trying circumstances. For example, on one of the missions a valve burned out in one engine on the way out. Once the decision had been made to continue the mission, it was accepted by all without question and although the engineer was busier than usual, no one showed any signs of worry.

Generally speaking, cabin temperatures are fairly comfortable, although the heat is often unevenly distributed so that the feet may be cold while it is hot at head level. Crowding is not excessive as compared with most other military planes, and it is sometimes possible for one or two crew members at a time to stretch out for naps. The flights become boring but probably less so than scheduled MATS flights. As previously stated, morale is excellent and relationships between crew members are very friendly. In-flight meals are above average in variety and there is always food to spare. In short, on the surface there is little reason to believe that the stresses of the mission are sufficient to produce adverse physiological reactions. However, it must be remembered that every crew member is well aware that no flight in the world is made over more inhospitable regions. It is difficult to assess the degree of strain to which some of the men may be exposed prior to the missions. It is known that at least some of the wives are not happy about the risks involved. Also, not infrequently a man may undertake one of these flights the day following a night spent on alert or as duty officer, or after having had only four hours' sleep for various personal reasons.

Light intensities were measured at each crew station at least once every half-hour. Weston and General Electric exposure meters were used for this purpose. The meter was held as close as practicable to the eyes of the subject and pointed in the direction in which he was looking. Readings during the May and July trips varied all the way from barely measurable up to off-scale on the bright side. During the December trip most positions gave negligible readings. In view of the crudity of our measurements and the apparent absence of a positive effect of the light exposure encountered on the night visual acuity of any crew member, there does not seem to be much point in reporting the measurements in detail. The positions rank in approximately the following order in light intensity to which the crew members are exposed: Weather observer, pilots, scanners, flight engineer, radar operator and navigators (except while making fixes on the sun), and finally the radio operators. The navigators and radio operators work almost in darkness at all times of the year, except for small desk lamps. The flight engineer receives reflected sunlight through the astrodome and the nose at certain times and spends a fair amount of time visually checking the engines. The scanners receive bright light from one side only and do not spend much time looking into the sun. Light is very strong in the nose and cockpit at all times during the daylight hours, but the brightest sources other than the sun itself are the clouds above and below. The weather observer is in the most exposed position and his duties require him to study the clouds and to record data on paper which is frequently in direct sunlight. The subjective sensation is one of overall glare in the exposed positions but not of particularly intense light. The light is probably less than would be received in the open on snow-covered ground on a sunny day.

The majority of crew members in exposed positions wear dark glasses most of the time, but there are exceptions. On one mission, the right scanner spent most of the return trip reading a book. During this time the sun was on his side and slightly behind him shining directly on his book, which presented a blinding glare of white. The observer could barely see the print in the glare while measuring the light intensity. (Inasmuch as the book presented only a small area, the value, while high, was not spectacular.) From time to time the scanner would glance up at the glistening wing of the plane which was reflecting the sun like a mirror. For two and one-half hours by the clock, the scanner underwent this exposure without glasses of any kind. Finally, after the sun had fallen far enough behind so that the book was in his shadow, he put on a pair of small, ten-cent store type green glasses. In the ensuing test, this particular man almost doubled his preflight score. On the same mission, the other scanner and one of the pilots wore dark glasses only intermittently. This particular crew had devised a public address sytem with two speakers, so that only the radio operators needed to wear headsets. Many crew members complain of mechanical discomfort due to wearing glasses under headsets and frequently take off their glasses to rest the ears and the bridge of the nose. We were unable to detect any significant effect of the wearing of sunglasses on subsequent night vision. There is no doubt that the glasses are desirable to relieve eye strain and most men would not be without them, but apparently the intensity of the light to which crews are exposed on these flights is not great enough to affect the night vision, even without glasses.

No crew member used supplemental oxygen at any time on any of the five missions in which we participated. However, we have talked to a number of members of other crews who regularly wear their oxygen masks for about half an hour before landing, and at our request but not without some complaints, oxygen was used by all crew members during the last 30 minutes before landing on all November and January missions. According to these men, the use of oxygen at this time has a very stimulating and invigorating effect, and one pilot reported that he was aware of marked subjective improvement in his vision immediately after putting on his mask. Since all crew members carry oxygen masks, it seems a little strange that so many would neglect to use them considering the evident satisfaction of those who do.

The nutritional status of these men was the subject of another study, and will be reported in detail elsewhere. However, it may be said here that the men were receiving in excess of 5,000 IU of vitamin A per day. This figure is based on individual food weighings over several days and represents consumption and not mere availability. The daily averages range from 3,500 IU to 21,500 IU for a representative group of men, but the long-term average exceeds 5,000 IU per day.

DISCUSSION

Hecht et al. found that a single exposure of two or three hours to sunlight on tropic beaches delays the onset of subsequent rod dark adaptation by ten minutes or more and increases by several hours the time required to reach the normal night vision threshold. Moreover, the effects of repeated daily exposures are cumulative and individuals exposed to sunlight day after day without protection eventually suffer an average deterioration of 50% in night visual acuity, range of visibility, contrast discrimination and frequency of picking up a barely visible target. This effect does not disappear even after 10 days of protection from sunlight.

There is little doubt that similar effects would be experienced by men on snow-covered ground during late spring and summer. Moreover, under these conditions snow blindness may also ensue. However, it is obvious from Table II that men are not exposed to anything like these light intensities while engaged in polar flights at operational altitude. In the current study, deterioration of night visual acuity occurred only during the dark months and must be ascribed to the operation of some factor other than light exposure. It is difficult to say what this factor or factors might be. However, it seems logical to assume that fatigue, both mental and physical, and apprehens would be greater during the dark months. The prospect of being forced down in the dark and in the arctic winter is not a pleasant one.

It is not possible at this time to account with certainty for the increased night visual acuity following the two July missions. However, ther seem to be two possibilities: First, that the subjects were actually exposed to less light during the missions than during the days preceding the preflig tests and that consequently their thresholds at the time of the postflight tests were lower than the normal summer level. Second, that during the long flights at a pressure altitude of 8,500 feet, they became partially acclimati to altitude and that upon subsequent descent to ground level they retained th physiological advantage long enough to better their previous scores.

With regard to the first possibility, it may well be that certain crew members were exposed to less light during the flight than while on the ground but it is hard to believe that the majority were. Moreover, it rained and drizzled with a very heavy overcast all day on one of the days the preflight tests were administered, whereas the flights were carried out in bright sunlight. Also, if the normal daily light exposure of the men had been stron enough to elevate the preflight thresholds, even after a dark adaptive period one would not have expected the effect to disappear after only one day of protection from excessive light. It will be recalled that Hecht found that normal threshold levels were not regained even after 10 days of indoor activi Finally, Table II shows that the preflight thresholds were lower in July than in December, although of course different subjects were involved.

Concerning the second possibility, Rose in 1949 (2) found that twilight visual acuity, which after a short stay at a simulated high altitude in the decompression chamber shows a marked decline, is restored to normal within 24 hours at actual altitudes of 6,500 to 10,000 feet. He also found that the brightness threshold was restored to normal or even better than normal values within 24 hours at these altitudes. In the current studies, pressure altitudes within this range were maintained for a very considerable fraction of this length of exposure and might be expected to produce similar effects. Furthermore, Rose's measurements were made with the subjects still at altitude. To our knowledge no one has yet measured night visual acuity at ground level following long exposure to altitudes sufficiently high to affect night visual thresholds. It may well be that a still further improvement beyond normal levels would occur under these conditions. In opposition to this explanation are the detrimental effects of the November and January Ptarmigan missions, and, to a lesser extent, the absence of effects in the remaining cases. However, as mentioned previously, there are other physiological and psychological stresses to be considered, and these would be expected to have their greatest effect during the winter.

On the whole, the authors are inclined to accept the second or acclimatization hypothesis as a basis for further work. However, this laboratory does not have the facilities to conduct acclimatization tests in the decompression chamber and the work will have to be done elsewhere. In passing, it might be noted that, paradoxically, if this hypothesis is correct, the use of supplemental oxygen during prolonged flights in pressurized or medium altitude aircraft would be detrimental to subsequent ground night vision by preventing short-term acclimatization. In this connection, it is interesting to note that supplemental oxygen was employed prior to landing on the first four missions only. All missions which produced adverse effects on night visual acuity were in this group. It is clear that supplementary oxygen, at least when employed for only short periods immediately prior to landing, does not have any protective effect on subsequent night visual acuity. While it is not meant to imply that the use of oxygen per se is detrimental, it does seem possible that under these conditions oxygen might unmask the effects of fatigue, etc., by diminishing the degree of acclimatization attained during flight.

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