STUDIES ON RETINAL SENSITIVITY SHORTLY AFTER TAKE-OFF IN DARKNESS.

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In night flying an efficient working of the visual mechanism for low levels of illumination is of particular importance at the time of take-off, the period immediately following it, and during landing. At the latter instance, the pilot has had time to adapt his eyes to the prevailing brightness throughout the course of the flight and should, therefore, be at little or no disadvantage. At the time of take-off, on the other hand, the situation is different. Due to the effects of previous and simultaneous illumination such as artificial lights in the flight offices and crew rooms, at dispersal points, and from other unavoidable sources, it is usually assumed that the sensitivity of the pilot's eyes at the time of take-off is considerably lower than its fully adapted threshold (Craik). This assumption had resulted in use of pre-flight adaptation, which according to Livingstone is of real value. It is impracticable, however, to continue pre-flight adaptation during the taxying phase. The effect of subsequent exposure to unavoidable lights on the airfield has not yet been ascertained. Further there is no report available in literature which deals with the measurements of retinal sensitivity at the actual time of take-off and shortly afterwards. The present work is an attempt to fill in these gaps.

Method

The sensitivity of the eyes shortly after take-off as compared with that of the eyes when fully dark adapted was assessed in terms of the relative brightness at which pilots were able to perceive simple standard forms. For full adaptation a period of 45 mts. in the dark was considered sufficient since it is known that for all practical purposes the rate of improvement in sensitivity of the eyes is extremely slow after this period (Duke Elder). The apparatus used for the purpose of this study was the A.R.L. Adaptometer MK IV.

This instrument consists of a rectangular box with a lamp at one end and a circular glass viewing screen at the other, in front of which is an opaque sector. This sector can be placed in eight positions of the clock face at 1½ hours intervals e.g. 12, 1-30, 3 etc. The brightness of the screen can be varied by insertion of one or other of a series of 16 graded apertures at a point about half way between the lamp and the screen. Screen brightness is expressed by the number of the aperture in use and decreases as this number decreases. Thus the highest brightness is given by the aperture 16 and the lowest by the aperture 1. The brightness with any aperture in position is higher by about 25% than that with the next lower aperture.

The subject was seated at a distance of 6 feet in front of the viewing screen. With

aperture 16 in position at the start, he was required to report the position of the sector. On every two consecutive correct answers, the time from the commencement of the experiment was recorded and the aperture was reduced by one. The smallest aperture at which the position of the sector was correctly indicated at the end of the period of observation was taken as the subject's brightness threshold at that time. An additional half grade was credited to the subject if he lingered at the next smaller aperture giving several correct, but no consecutive responses.

Preliminary tests were carried out on a group of airmen in order to determine the consistency of results and the effect of learning as a result of repeated testing. For this purpose a group of 30 healthy airmen with normal vision between the ages of 19½ and 34 were selected. Seven airmen dropped out at the early stages of the experiment and so are excluded from the study. For the fifth and the final test, only 12 airmen were available. The tests were carried out between 0900 and 1300 hours. The airmen were kept for a minimum period of half an hour in a room artificially lighted with an average illumination of 2.5 lumens/sq. ft. at table top level. They were given detailed instructions on the test procedure and on the use of off-centre vision. Adaptometer readings were then taken at the end of 15 mts. and 45 mts. in complete darkness. The former were designated as partial adaption (P.A.) scores and the latter, full adaptation (F.A.) scores. This procedure was repeated on 5 different days for each individual.

Tests were then carried out on 7 pilots, between the ages of 22 and 29 with a visual acuity of 6/6 or better and having sufficient experience in night flying. The pilots were exposed to normal crew room lighting (average illumination at table top level 3.5 lumens/sq. ft.) for a minimum period of one hour. The experiments commenced between one to two hours after sunset and were carried out in a completely darkened chamber. Pilots were briefed in advance as to the test procedure and the use of off-centre vision. The Adaptometer readings were recorded continuously during a 45 minutes period in the dark. The tests were repeated on 4 different occasions.

A second series of readings were taken after the pilots, on being exposed to crew room lights for an hour or more, taxied an aircraft to the take-off point of runway in use. This, incidentally, entailed maximum exposure of the pilot's eyes to the airfield lights. These tests were carried out in a mobile dark chamber located near the take-off point. Adaptometer readings were recorded for a period of 15 minutes in darkness. It was not possible with this apparatus to assess correctly the level of dark adaptation immediately the pilot entered the dark examination chamber. However, it was possible to obtain accurately scores at 5 minute intervals and these have been considered to represent scores estimated at 5, 10 and 15 minutes after take-off on dark nights. The time intervals between the commencement of taxying and the commencement of the test was recorded in each case. Two sets of readings were taken for each individual on two different occasions.

Results

Table I gives the individual scores of partial adaptation (15 mts. in dark) on the

23 airmen. The table reveals progressive improvement in the scores from the Ist to the 4th test. The last column in the table gives the overall effect of learning as a result of repeated tests. The mean overall improvement in partial adaptation due to learning is of the order of 2.15 grades and is highly significant. The individual scores for full adaptation

TABLE I

Results of the first four partial adaptation tests of airmen.

Sub. No.	Ist test P.A.1.	2nd test P.A.2.	3rd test P.A.3.	4th test P.A.4.	P.A.1.—P.A.4.
1	10.5	10.0	9.0	8.5	2.5
2	14.0	13.0	12.0	11.5	2.5
3	12.0	12.0	11.0	11.0	1.0
4	11.5	9.5	8.5	8.0	3.5
5	12.0	11.0	12.0	12.0	0.0
6	12.0	11.0	11.0	11.0	1.0
7	14.0	12.0	12.0	12.0	2.0
8	9.0	8.0	8.5	8.5	0.5
9	9.5	7.0	7.0	7.0	2.5
10	11.0	8.5	8.0	8.5	2.5
11	14.0	12.0	11.0	11.0	3.0
12	12.5	8.0	7.5	8.5	4.0
13	9.0	8.0	8.5	7.0	2.0
14	9.5	9.0	10.5	9.0	0.5
15	11.0	11.5	8.5	9.0	2.0
16	11.0	10.0	9.0	7.0	4.0
17	9.0	8.0	9.0	8.5	0.5
18	14.0	12.0	12.5	10.0	4.0
19	11.0	8.5	7.5	8.0	3.0
20	10.0	9.0	10.0	8.0	2.0
21	10.0	8.5	8.0	8.0	2.0
22	11.0	11.0	10.5	8.5	2.5
23	10.0	10.5	11.0	8.0	2.0
Mean	11.2±0.36	9.91±0.36	9.67±0.36	9.07±0.33	2.15±0.2

(45 mts. in dark) are given in table II. The mean overall improvement in full adaptation is 1.24 grades and is significant. The overall improvement in the case of partial adaptation is more than in the case of full adaptation. The scores obtained by 12 airmen in the 4th and 5th

TABLE II

Results of the first four full adaptation tests of airmen.

Sub No.	1st test F.A.1.	2nd test F.A.2.	3rd test F.A.3.	4th test F.A.4.	F.A. 1—F.A. 4.
1	6.0	6.5	4.5	4.0	2.0
2	7.0	7.0	7.5	7.0	0.0
3	9.0	8.0	8.0	8.0	1.0
4	8.0	7.0	5.0	4.0	4.0
5	8.0	6.0	8.0	7.0	1.0
6	8.0	8.0	7.0	7.5	0.5
7	9.0	7.5	9.0	7.0	2.0
8	6.0	6.0	6.0	5.5	0.5
9	6.0	5.0	5.5	5.0	1.0
10	6.0	4.0	3.5	4.0	2.0
11	8.0	9.0	8.0	7.0	1.0
12	8.0	7.0	5.0	5.0	3.0
13	5.0	5.0	6.0	6.0	1.0
14	8.0	7.0	6.5	6.5	1.5
15	7.0	6.0	5.0	6.0	1.0
16	7.0	7.0	7.0	6.0	1.0
17	9.0	7.5	7.5	8.0	1.0
18	10.0	9.5	8.5	8.0	2.0
19	6.0	5.0	7.0	6.0	0.0
20	7.0	5.5	5.5	6.5	0.5
21	7.0	6.5	5.5	6.5	0.5
22	8.0	6.0	6.0	6.0	2.0
23	4.5	5.5	5.5	4.0	0.5
Mean	7.28 ± 0.29	6.57 ± 0.27	6.30 ± 0.29	6.04 ± 0.27	1.24 ± 0.24

tests after partial and full adaptation are given in table III. There is no significant difference between the scores of the 4th and 5th tests showing thereby that there is no further improvement due to learning after the 4th test. Thus the scores obtained in the 4th test may be taken as final. The mean of the scores in the fourth test is 9.07 for partial adaptation (Table I) and 6.04 for full adaptation (Table II). The mean of the difference between the partial adaptation and full adaptation scores on the 4th test is found to be 3.02. This is slightly lower than the mean of the difference between the partial adaptation and full adaptation scores on the first test (3.91), since the overall improvement in the partial adaptation

TABLE III

Results of the 5th partial and full adaptation tests of airmen compared with those of the the 4th tests.

Sub No.	4TH TEST P.A.4.	F.A.4.	5TH TEST P.A.5.	F.A.5.	P.A.4—P.A.5	F.A.4—F.A.5
1	8.5	4.0	9.0	4.0	−0.5	0.0
2	11.5	7.0	12.0	6.0	−0.5	1.0
4	8.0	4.0	9.0	4.0	−1.0	0.0
5	12.0	7.0	12.0	7.5	0.0	−0.5
6	11.0	7.5	10.0	7.5	1.0	0.0
8	8.5	5.5	8.0	6.0	0.5	−0.5
10	8.5	4.0	9.0	4.0	−0.5	0.0
11	11.0	7.0	10.0	7.0	1.0	0.0
12	8.5	5.0	8.5	6.0	0.0	−1.0
13	7.0	6.0	7.5	6.0	−0.5	0.0
16	7.0	6.0	8.0	6.5	−1.0	−0.5
23	8.0	4.0	9.0	4.0	−1.0	0.0
Mean	—	—	—	—	−0.21±0.21	−0.12±0.14

TABLE IV

Partial and full adaptation scores of the pilots in the 4th test.

Sub. No.	4th test. P.A.4.	4th test F.A.4.	P.A.4—F.A.4.
1	8.0	4.5	3.5
2	7.0	5.0	2.0
3	6.0	4.0	2.0
4	7.0	4.0	3.0
5	8.0	4.5	3.5
6	7.0	4.5	2.5
7	9.0	6.0	3.0
Mean	7.43 ±0.31	4.64±0.28	2.78±0.26.

scores is higher than in the case of full adaptation.

Table IV gives the individual scores of partial (15 mts. in dark) and full (45 mts. in dark) adaptation as recorded in the 4th and the final test on 7 pilots after their eyes had been previously exposed to the normal lights in the crew room for a period of at least one hour. The means of the partial and full adaptation scores are 7.43 and 4.64 respectively. These scores are significantly better than the corresponding scores in the case of the airmen. The difference

between partial and full adaptation scores is 2.78 and is slightly less than in the case of airmen. In table V are shown the scores obtained by the pilots at the end of 5, 10 and 15 mts. in the dark after they had taxied an aircraft to the point of take-off. The score of each individual

TABLE V

Comparison of partial adaptation scores of pilots, 5, 10 and 15 mts. after "take-off" with their full adaptation scores.

Sub. No.	P.A 5(5mts. after taxying).	P.A.10(10 mts after taxying)	P.A.15(15 mts.after taxying).	P.A.5-F.A.	P.A.10-F.A.	P.A.15-F.A
1	8.0	6.5	6.25	3.5	2.0	1.75
2	6.5	5.5	4.5	1.5	0.5	0.50
3	7.0	5.5	4.0	3.0	1.5	0.0
4	8.0	7.5	5.75	1.0	3.5	1.75
5	8.0	7.5	6.0	3.5	3.0	1.50
6	7.0	7.0	6.25	2.5	2.5	1.75
7	9.5	9.0	8.25	3.5	3.0	2.25
Mean	7.71±0.38	6.92±0.47	5.86±0.52	3.07±0.31	2.28±0.38	1.21±0.34

Note: *The scores after taxying represent the mean of two observations on each pilot.*

is compared with his full adaptation score. The means of the difference between the full adaptation score and that obtained 5, 10 and 15 mts. after taxying are 3.07, 2.28 and 1.21 respectively and represent the number of grades by which the sensitivity of the eye falls short of its sensitivity when adapted for 15 mts. in the dark.

TABLE VI

Partial adaptation after exposure to normal crew room lighting compared with partial adaptation at the end of 15 mts. in the dark, inclusive of the period of taxying.

Sub. No.	4th test P.A.4(15mts. in darkness after leaving the crew room).	P.A.(15mts.after leaving crew room and taxying aircraft).	a-b
	(a)	(b)	
1	8.0	7.0	1.0
2	7.0	7.0	0.0
3	6.0	6.5	−0.5
4	7.0	7.5	−0.5
5	8.0	8.5	−0.5
6	7.0	7.0	0.0
7	9.0	9.0	0.0
Mean	7.43±0.34	7.5±0.34	−0.07±0.19

In table VI the period of taxying is included in the 15mts. period spent in the dark. Thus, if the period spent in taxying was 7mts. the partial adaptation level reached after 8 mts. in the dark examination chamber was determined. These scores are compared with the partial adaptation scores after exposure to normal crew room lights. The mean of the difference between the scores is found to be insignificant.

Discussion

The threshold of brightness for simple form perception is lower in the case of pilots than it is for the airmen. The experience of the pilots in the use of their eyes under low levels of illumination may be responsible for this difference. However, the fact that the pilots were tested in the night and the airmen in the day should be borne in mind.

The score obtained by the pilots at the end of 5 mts. after "take-off" falls short of the score of fully dark adapted eyes by 3.07. Since the brightness of any aperture on the A.R.L. adaptometer is higher by about 25% than that of the next lower aperture, a difference in the grade by 3.7 indicates that 5 mts. after "take-off" the pilots have a brightness threshold which is higher than that of the fully dark adapted eyes by about 95 per cent. The scores at the end of 10 and 15 mts. after "take-off" fall short of the scores of fully adapted eyes by 2.28 and 1.21 and represent brightness thresholds higher than that of the fully dark adapted eyes by about 65 and 30 per cent respectively.

It is evident from the above results that at the time of take-off and even after a flight of 15 minutes in darkness the efficiency of the visual mechanism for low levels of illumination falls short of its maximum and, therefore, some form of protection against exposure to lights prior to take-off is necessary. As far as the lights in the crew room are concerned, it is possible to minimize the effect either by the use of red lights or by wearing red adaptation goggles. Since it is not possible to wear goggles for taxying, it may be argued that the effect of pre-flight adaptation in the crew room may be offset by subsequent exposure to unavoidable lights on the airfield. However, since the dark adaptation 15 minutes following exposure to crew room lights is of a lower order than the partial adaptation 15 minutes after "take-off", it follows that the period of taxying contributes towards dark adaptation. The mean of the difference was found to be 1.57 and is highly significant. Further evidence of this is provided by incorporating the period of taxying in the adaptation period, whereby the difference between the scores so obtained and those after 15 minutes dark adaptation following exposure to crew room lights becomes insignificant (vide Table VI). It could, therefore, be concluded that despite the exposure to extraneous lights, the period of taxying has the same effect as a stay in darkness for the same period.

Conclusions

In using the A.R.L. adaptometer for determining the capacity for simple form perception under varying conditions, it is first essential to repeat the test on four different occasions, after which it yields fairly uniform results under any standard conditions.

Under the experimental conditions described above, the brightness levels required for simple form perception after 5, 10, and 15 minutes from the time of "take-off" are higher than that of the fully dark adapted eyes by about 95, 65 and 30 per cent respectively.

If pilots were to practise pre-flight adaptation in the crew room, there is no evidence to indicate that the state of their dark adaptation would be interfered with by exposure to airfield lights during the taxying period.

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