A STUDY OF THE SLEEP MOTILITY OF STUDENT PILOTS

by

Frank A. Goldard

A report on research conducted at the University of Virginia, University, Virginia, by means of a grant-in-aid from the Committee on Selection and Training of Aircraft Pilots of the National Research Council, from funds provided by the Civil Aeronautics Administration.

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Executive Subcommittee

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NATIONAL RESEARCH COUNCIL

2101 Constitution Avenue, Washington, D. C.
Division of Anthropology and Psychology

Committee on Selection and Training of Aircraft Pilots

April 1, 1944

Dr. Dean R. Brimhall
Director of Research
Civil Aeronautics Administration
Washington, D. C.

Dear Dr. Brimhall:

Attached is a report entitled A Study of the Sleep Motility of Student Pilots by Frank A. Geldard. This report is submitted by the Committee on Selection and Training of Aircraft Pilots with the recommendation that it be included in the series of technical reports issued by the Division of Research, Civil Aeronautics Administration.

The report is of interest in describing a technique for investigating the emotional disturbances which may develop during flight training. The findings of a preliminary study using this technique are also presented.

Cordially Yours,

Morris S. Viteles Chairman
Committee on Selection and
Training of Aircraft Pilots
National Research Council

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EDITORIAL FOREWORD

The study presented in this report was begun in 1939 under the sponsorship of the Committee on Selection and Training of Aircraft Pilots. The investigation of the problems of sleep motility reflects the Committee's early interests in investigating emotional aspects of flight training and of flight performance.

The present study suffers from lack of sufficient numbers of cases and from the absence of data on students' flight performance during training. It remains to be determined, therefore, whether the differences or trends found in this study will hold up in larger samples and whether sleep motility is a measure of emotionality which is directly related to success or failure in flight training. Nevertheless, the report is of interest from the viewpoint of the aims in pilot research and of methodology.

CONTENTS

SUMMARY

In the early days of research on problems involved in the selection and training of aircraft pilots one of the principal areas under investigation was that of the emotional aspects of flight training. Such factors as increased "tension" aroused in the student pilot by the flight situation; "nervousness"; "sweating"; etc., were set aside for study in relation to the student's success or failure in flying.

As one step in investigating the emotional aspects of flight, a study of movements during sleep was undertaken. In order to investigate this sleep behavior a specially constructed instrument (the Simmons Kinetograph, slightly modified) was attached to the beds of a class of 12 student pilots undergoing C.P.T. training at the University of Virginia. This instrument records on a graphic record all of the major (trunk) and minor (head and limb) movements of the student while he is asleep.

In general, the results of the study were negative, i.e., after analyzing the records of these students (a) under normal living conditions before beginning their flight training, (b) following days on which flight lessons were given, and (c) following days during the training on which no flying was done, few significant changes were noticed in the sleep motility. This general conclusion seems to hold, whether the amount of time spent in movement during sleep or the magnitudes of the movements made are considered.

It must be pointed out, however, that some of the students did change significantly in their sleep behavior. If a large group of subjects were studied, changes might occur in sleep motility frequently enough to be of value in the selection of pilots.

Unfortunately, the present study does not show whether those students who did change significantly in their sleep behavior were the ones who were good or bad in flying or who passed or failed the flight course. Until it can be shown that changes in sleep motility are characteristic of good or bad pilots, or passing or failing students, the chief value of the present study is to point the way for further experimentation along these same lines.

A STUDY OF THE SLEEP MOTILITY OF STUDENT PILOTS[1]

THE PROBLEM

Stated in general terms, this problem involved an intensive study of the sleep performance of a group of flight students. At the beginning of the experiment the students were receiving ground school instruction. These same students were then studied after they had taken up actual flight instruction. When sufficient records were available there was an attempt to isolate sleep motility norms for each of the individuals studied. The records collected were then compared with other records gathered at critical intervals, viz., nights before and after actual flight lessons, novel maneuvers, etc. It was hoped that out of such an analysis would come some measure of the sleep behavior of the student pilot which would correlate significantly enough with flying ability or performance to be of practical predictive value.

Specifically, the problem consisted of a detailed analysis of the sleep motility of student pilots with a view to determining:

1. Whether flight training altered or interfered with the normal sleep behavior of the student pilot, and

2. Whether the sleep behavior of student pilots reveals any stable characteristics.

THE SUBJECTS

An experimental group of twelve subjects was selected from a larger group of forty students who were enrolled in the ground-school courses of the Civilian Pilot Training Program being carried on at the University of Virginia in 1939. Twelve subjects were selected for study on the basis of the following criteria:[2]

1. The probable availability of the subjects for continuous study. Thus, third year men were selected where possible because they would be the most likely ones to continue their work in the University during the following year.

2. The accessibility of the experimental laboratory to the subjects. All twelve of the subjects finally selected lived in fraternity houses, apartments, and rooming houses within a one-mile radius of the laboratory.

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[1] The writer wishes to acknowledge the contributions of Dr. H. M. Johnson, Dr. C. G. Wilder, and Mr. H. R. Manchester, Jr., to the conduct of this study.

[2] It is regrettable that the subjects could not have been selected on the basis of those who would have flight instruction under the same instructor. Such selection would have given a valuable set of flight ratings which could have been included in the analysis.

3. The similarity of the subjects' sleeping equipment. Only those who had essentially the same bedding equipment were selected in order to avoid complications in mounting and adjusting the sleep motility recorders. Eleven of the subjects had flat-spring, single beds; one had a coil-spring bed.

4. The ease of contact at the beginning of the study.

APPARATUS AND PROCEDURE

The method employed throughout this study involved the use of the Johnson Sleep Motility Recorder (Simmons Kinetograph).[3] One recorder was attached to the bed of each of the twelve experimental subjects.

The entire recording unit of this apparatus (the Kinetograph, the Telechron clock, the control clock, and the necessary dry cells) was mounted on a wooden platform and suspended from the side bedrails. In all instances it was necessary to increase the clearance of the bed spring from the floor to accommodate the recorders. This was accomplished by jacking up the bed posts with either six-inch or eight-inch wooden blocks. The slide carrying the recorder pens was attached in the conventional manner to the bed spring with a linen cord and was adjusted in each case to give a one-millimeter deflection with the passive dropping of the subject's arm to his side. In all instances, this required a displacement of the longitudinal axis from the center of the system towards the foot of the bed.

The recording drums were driven by quiet "Green Flyer" two-speed phonograph motors. The recording pens were made up of right-angle glass points[4] and cemented with liquid solder to the inside walls of 32-caliber cartridges. This provided an ink well large enough to hold a two to three days' supply of ink and gave a very fine line on the recording paper. Esterline-Angus red recording ink proved to be the most satisfactory for use in conjunction with these improvised pens.

A time mark was obtained in the records for each minute during operation of the recorder. This was accomplished through the expedient of using Telechron wall clocks of the common kitchen variety having a single wiping contact on the sweep hand. This time mark was actuated by means of ordinary dry cells. Control clocks ("Tymits") were used for starting and stopping the entire machinery. These clocks were set to begin recording at 10 p.m. and to stop at 9 a.m.

It was reported by some of the subjects that for a few nights the slight monotonous noise of the recorder was bothersome. However, all subjects became throughly accustomed to it in the early stages of the study.

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[3] The writer is indebted to Dr. H. M. Johnson for his aid in procuring these instruments. Dr. Johnson had previously made extensive use of this apparatus in his studies of sleep carried on at the Melon Institute.

[4] These right-angle glass points were supplied by the Esterline-Angus Company.

The recorders were serviced daily, the record of the previous night being removed, the recording paper adjusted to receive the next record, and the necessary adjustments of the pens, driving machinery, etc., being made. It might be noted that certain difficulties with the apparatus were encountered early in the study. These were, primarily: accidental disconnection of the electric plugs, excessive inking and tearing of the recording paper by reason of the subjects' failure to keep off the beds in the daytime (when the recorders were stopped), occasional slopping of the recording ink, and the breaking of the recording pen tips resulting from jumping on the beds. In one instance, double occupancy of the bed invalidated the record for purposes of this study. However, once the servicing routine had become well established and cooperation had been received from the subjects, these difficulties disappeared and useable records were obtained without interruption.

Nothing was done during the course of the study to interfere with the normal living habits of the twelve subjects. It might have been better for experimental purposes to use a population whose habits relative to retiring and arising were less erratic than these. Life in local fraternity houses and rooming houses is characterized by great irregularity. No effort was made to obtain supplementary data on the daily non-sleeping performance of the subjects.

THE DATA

It was possible to begin the extensive task of analysis of the records within a few weeks after the beginning of the study. It was decided, at the outset, to avoid excessive handling of the records by taking a variety of measures at the same time. The following were tabulated for each record.[5]

1. The date.
2. The number of "active" minutes in bed. (An active minute is defined as a one-minute interval in which at least one movement occurs; several movements may, of course, occur.)
3. The total number of minutes of occupancy of the bed.
4. The number of "active" minutes during the sleep period. (Sleep was regarded to have intervened at the beginning of the first five-minute period of quiet.)
5. The total number of minutes in sleep.
6. The total number of individual movements during sleep (without regard to the interval in which they occurred).

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[5] The differentiation between the major and minor movements (13 and 14) is explained later in the paper.

7. The number of five-minute "active" periods in bed.

8. The total number of five-minute periods in bed.

9. The number of five-minute "active" periods during sleep.

10. The total number of five-minute periods in sleep.

11. The maximum amplitude of displacement of the recording pen from the position of non-occupancy (a measure of the sensitivity of the recording system).

12. The computation of one-quarter of the above value (the line of demarcation between major and minor sleep movements).

13. The total number of minor (head and limb) movements during sleep.

14. The total number of major (trunk) movements during sleep.

Sleep was defined for purposes of this investigation as the time between the beginning of the first five-minute "passive" period after entering the bed and the end of the last five minutes of quiet before leaving the bed. In those cases where the record revealed that the subject had left the bed temporarily during the course of the night, it was necessary to reapply the criterion of sleep upon his reoccupancy of the bed.

A preliminary comparison of the one-minute and five-minute scoring methods indicated a very considerable difference between the two.[6] While most of the previous studies on sleep have regarded the five-minute interval as the smallest they wished to consider for scoring purposes it seemed desirable to determine what the effect would be of narrowing the class interval. This preliminary analysis revealed that scoring in terms of one-minute intervals, while still distorting the picture considerably, was sufficiently closer to actuality than was the five-minute scoring method to warrant the use of the former.

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[6] In order to make this preliminary comparison, a high-speed recorder was introduced and comparisons made on the same record of three different scoring procedures. This new recorder operated at about one hundred times the paper speed of the standard recorders. Analyses were made of a single night's records with the following results:

For a record covering 454 minutes in bed, there were 167 discrete movements requiring a total of 8.99 minutes. Thus approximately 2% of the time in bed was actually spent in movement. (This included movements getting into and out of bed.) There were 166 periods of rest, averaging 2.67 minutes in length, and ranging from 0.5 seconds to 33.8 minutes. The same record showed there to be 102 "active" minutes, or 22% of the total number spent in bed. The number of "active" five-minute intervals in the same record was 52, or 57% of the total of the five-minute intervals. On the average, about 9% of an "active" minute proved to be really active, with a range from 0.8% to 41%. On the average, 3.4% of the five-minute "active" intervals was really active, the range being from 0.2% to 13.7%.

This preliminary analysis was conducted by Mr. M. M. Jackson.

For purposes of the entire study a "one-minute motility index" was devised. This was calculated as the ratio between the number of "active" one-minute intervals and the total number of one-minute periods spent in sleep. A similar measure was computed for the five-minute periods of sleep and was called the "five-minute motility index."

RESULTS

In the presentation and systematization of the results, distinction is made between four (experimental) conditions: (1) Records for "normal" (pre-flight) nights are included in the first category; (2) Records for the nights following the days on which a flight was made are put in the second category; (3) Records for the nights following non-flight days during the course of training made up the third; and (4) A combination of the first and third categories made up the fourth (since there might be good reason for considering all non-flight records as being "normal").

<u>One-minute motility indices.</u> In Table I are presented the means and standard deviations of the one-minute motility indices for each of the twelve students under each of the four experimental conditions. It will be noted that the means range from .083 to .179 and that the variability is somewhat large.

TABLE I

ONE-MINUTE MOTILITY INDICES FOR THE FOUR EXPERIMENTAL CONDITIONS
(Means and standard deviations of 12 subjects)

Subject	Normal Nights	S.D.	Flight Nights	S.D.	Non-flight Nights	S.D.	Normal and Non-flight (comb.)	S.D.
1.	.143	.042	.153	.012	.151	.040	.146	.038
2.	.140	.028	.143	.032	.155	.030	.151	.025
3.	.135	.035	.241	.04[illegible]	.153	.025	.146	.031
4.	.139	.032	.145	.026	.132	.023	.134	.027
5.	.136	.034	.135	.029	.131	.026	.134	.030
6.	.084	.018	.083	.019	.085	.01[illegible]	.084	.017
7.	.153	.014	.175	.012	.176	.036	.169	.038
8.	.179	.037	.162	.037	.167	.038	.170	.038
9.	.151	.033	.145	.036	.149	.024	.152	.027
10.	.092	.019	.092	.019	.065	.024	.085	.025
11.	086	.023	.111	.035	.107	.027	.100	.028
12.	.138	.039	.158	.026	.157	.029	.152	.034

In Table II are presented the critical ratios of differences between the mean one-minute motility indices of the different experimental conditions, i.e., normal versus flight nights, flight versus non-flight nights, and flight versus the combined normal and non-flight nights. All but three such comparisons yield statistically unreliable differences. The three exceptions were those for the normal versus flight nights in the cases of Subjects 7, 11, and 12. All three of these subjects show a reliably higher motility on nights following the days on which flights were made. For the group as a whole there is no uniformity in the direction of the differences.

TABLE II

CRITICAL RATIOS OF DIFFERENCES BETWEEN MEANS OF THE ONE-MINUTE MOTILITY INDICES

Subject	Normal vs. Flight	Flight vs. Non-flight	Flight vs. combined Normal and Non-flight
1.	.751	.109	.516
2.	.360	1.728	1.157
3.	.509	1.226	.505
4.	.437	.492	.109
5.	.013	.857	.436
6.	.286	.600	.361
7.	4.687	.161	.919
8.	1.354	.724	.946
9.	.937	.425	.959
10.	.053	1.380	1.362
11.	3.096	.519	1.493
12.	3.634	.145	1.175

Five-minute motility indices. Precisely the same computations were made using the five-minute motility index. The results of these computations are presented in Tables III and IV. On the basis of this index, only one of the subjects (Subject 11) shows a statistically reliable increase of sleep motility on the flight nights. It will be noted, however, that three other critical ratios are above 2.00, indicating an approach to significance.

Correlations between one-minute and five-minute indices. Correlations were computed between the one-minute and five-minute motility indices for each of the experimental conditions. All correlations ranged between .73 and .84. These correlations were somewhat higher than was suspected on the basis of preliminary comparisons of the two indices.

TABLE III

FIVE-MINUTE MOTILITY INDICES FOR THE FOUR EXPERIMENTAL CONDITIONS
(Means and standard deviations for 12 subjects)

Subject	Normal Nights	S.D.	Flight Nights	S.D.	Non-flight Nights	S.D.	Normal and Non-flight (comb.)	S.D.
1.	.425	.118	.483	.109	.470	.096	.462	.103
2.	.418	.054	.417	.065	.439	.079	.433	.063
3.	.436	.092	.464	.115	.486	.067	.465	.082
4.	.446	.063	.449	.066	.430	.054	.446	.061
5.	.478	.048	.462	.091	.464	.071	.466	.072
6.	.349	.055	.340	.045	.346	.064	.343	.063
7.	.429	.075	.484	.063	.486	.061	.468	.078
8.	.525	.069	.498	.094	.509	.069	.518	.075
9.	.497	.070	.460	.072	.493	.059	.497	.084
10.	.340	.060	.343	.063	.322	.066	.327	.065
11.	.327	.077	.418	.080	.399	.083	.374	.089
12.	.417	.085	.445	.072	.447	.062	.435	.072

TABLE IV

CRITICAL RATIOS OF DIFFERENCES BETWEEN MEANS OF THE FIVE-MINUTE MOTILITY INDICES

Subject	Normal vs. Flight	Flight vs. Non-flight	Flight vs. combined Normal and Non-flight
1.	1.453	.359	.593
2.	.087	1.306	1.170
3.	.951	.908	.045
4.	.186	1.311	.262
5.	.890	.102	.193
6.	.805	.492	.240
7.	2.063	.114	.936
8.	.996	.473	.887
9.	1.900	1.890	2.062
10.	.184	1.298	1.032
11.	4.095	.995	2.260
12.	1.451	.132	.695

Indices of major and minor movements. Since the motility records display magnitude of movement (to some degree) as well as the time of occurrence of the movement, an attempt was made to separate the major and minor movements made by the subjects. To determine whether such a separation could be effected, it was necessary to make a calibration of the individual records. Toward this end, a series of 122 predetermined movements, representing all single movements of the limbs, head and trunk, and combinations of these (at various speeds of the recorder) were selected for test. All movements judged to be relevant were included in this calibration and their selection was systematic.

It was found that a clear separation could be made between major (trunk) and minor (head and limb) movements in that distributions of the two (major and minor) did not overlap. The dividing point was found to be at an amplitude of approximately 25% of the total displacement occasioned when the subject entered (moved to) the center of the bed. In counting major and minor movements in the records, time intervals were disregarded so that the distributions of the total number of major and the total number of minor movements were arrived at. From these values a "major movement index" (the L index) and a "minor movement index" (the S index) were computed. The major movement index was defined as the total number of major (trunk) movements divided by the total number of movements made during sleep. The minor movement (S) index was computed in a similar manner.

Analyses were made of those indices in the same manner as was done for the one-minute and five-minute motility indices. Presented in Table V are the means and standard deviations of the L index (major movement) for the normal, flight, non-flight, and the combined normal and non-flight records for each of the twelve subjects. The critical ratios of differences between these means are presented in Table VI

TABLE V

THE L (MAJOR MOVEMENT) INDEX FOR THE FOUR EXPERIMENTAL CONDITIONS
(Means and standard deviations for 12 subjects)

Subject	Normal Nights	S.D.	Flight Nights	S.D.	Non-flight Nights	S.D.	Normal and Non-Flight (comb.)	S.D.
1.	.028	.009	.034	.013	.029	.009	.029	.009
2.	.028	.008	.040	.023	.042	.011	.039	.013
3.	.029	.013	.044	.018	.055	.017	.034	.017
4.	.031	.007	.026	.006	.026	.009	.030	.009
5.	.039	.013	.041	.011	.041	.013	.040	.013
6.	.042	.012	.046	.012	.045	.011	.043	.012
7.	.016	.008	.030	.017	.032	.013	.027	.014
8.	.057	.015	.046	.016	.047	.011	.050	.004
9.	.048	.013	.041	.015	.045	.012	.045	.012
10.	.036	.010	.039	.008	.036	.009	.036	.010
11.	.031	.011	.042	.014	.038	.013	.035	.012
12.	.022	.011	.025	.012	.030	.009	.027	.010

TABLE VI

CRITICAL RATIOS OF DIFFERENCES BETWEEN MEANS OF THE L (MAJOR MOVEMENT) INDICES

Subject	Normal vs. Flight	Flight vs. Non-flight	Flight vs. combined normal and non-flight
1.	1.279	1.071	1.300
2.	2.645	.378	.363
3.	3.465	2.454	2.525
4.	2.380	.389	2.500
5.	.517	.207	.200
6.	1.519	.160	1.000
7.	3.380	.463	.650
8.	3.545	.405	1.235
9.	1.897	1.111	1.088
10.	.821	1.364	1.353
11.	3.250	1.265	2.061
12.	.857	2.360	1.167

It will be noted that when the major movement index is employed in the analysis, a significant difference is found between the normal and flight records for Subjects 3, 7, 8, and 11. The differences in the means for Subjects 2 and 4 also approach significance. It must be noted, however, that not all of these differences are in the same direction. Indices for Subjects 4 and 8 show a decrease on flight nights, while those of Subjects 2, 3, 7, and 11 show an increase. The critical ratios for the flight versus the non-flight records for Subjects 3 and 12 also approach statistical significance. And, reliable differences are noted between the mean L indices of Subjects 3 and 4 for the flight versus the combined normal and non-flight records.

The same comparisons were made using the S (minor movement) index for the four conditions. The results of these computations are presented in Tables VII (means and standard deviations) and VIII (critical ratios).

It will be noted that the differences approach reliability for Subjects 11 and 12 in the normal versus flight records and for Subject 6 in the flight versus combined normal and non-flight records.

TABLE VII

THE S (MINOR MOVEMENT) INDEX FOR THE FOUR EXPERIMENTAL CONDITIONS
(Means and standard deviations for 12 subjects)

Subject	Normal Nights	S.D.	Flight Nights	S.D.	Non-flight Nights	S.D.	Normal and Non-flight (comb.)	S.D.
1.	.124	.036	.152	.054	.152	.041	.138	.039
2.	.148	.036	.157	.047	.165	.044	.160	.042
3.	.119	.031	.125	.046	.129	.032	.123	.032
4.	.128	.034	.128	.034	.127	.026	.127	.029
5.	.110	.033	.109	.028	.103	.024	.107	.029
6.	.056	.013	.048	.017	.057	.020	.057	.019
7.	.148	.034	.177	.047	.188	.044	.184	.041
8.	.139	.040	.147	[illegible]	.151	.043	.148	.042
9.	.138	.035	.129	.029	.137	.029	.138	.030
10.	.062	.021	.065	.021	.056	.022	.058	.022
11.	.060	.021	.080	.027	.080	.025	.074	.026
12.	.143	.047	.166	.030	.161	.034	.154	.040

TABLE VIII

CRITICAL RATIOS OF DIFFERENCES BETWEEN MEANS OF THE S (MINOR MOVEMENT) INDICES

Subject	Normal vs. Flight	Flight vs. Non-flight	Flight vs. combined normal and non-flight
1.	1.590	.017	.840
2.	.762	.743	.330
3.	.630	.301	.214
4.	.000	.041	.028
5.	.517	.207	.200
6.	2.294	2.190	2.576
7.	2.136	.857	.622
8.	.551	.389	.057
9.	1.125	1.149	1.319
10.	.476	1.792	1.471
11.	2.811	.121	.968
12.	2.432	.725	1.764

The next step was to compute the ratio between the major and minor movements (the L/S) index. Means and standard deviations of this index for the four conditions are presented in Table IX and the critical ratios in Table X.

TABLE IX

THE L/S RATIO (MAJOR/MINOR) FOR THE FOUR EXPERIMENTAL CONDITIONS
(Means and standard deviations for 12 subjects)

Subject	Normal Nights	S.D.	Flight Nights	S.D.	Non-flight Nights	S.D.	Normal and Non-flight (comb.)	S.D.
1.	.221	.091	.243	.107	.198	.079	.211	.087
2.	.194	.054	.291	.213	.270	.088	.246	.088
3.	.259	.095	.389	.196	.413	.134	.332	.167
4.	.243	.060	.220	.062	.217	.106	.227	.118
5.	.371	.152	.376	.113	.420	.192	.396	.175
6.	.827	.329	.855	.370	.853	.324	.837	.329
7.	.105	.057	.174	.128	.183	.075	.161	.079
8.	.450	.218	.316	.022	.333	.014	.365	.136
9.	.335	.129	.329	.132	.344	.113	.339	.135
10.	.661	.253	.626	.241	.698	.296	.688	.281
11.	.553	.308	.558	.188	.495	.168	.516	.221
12.	.166	.085	.137	.066	.196	.015	.183	.082

TABLE X

CRITICAL RATIOS OF DIFFERENCES BETWEEN MEANS OF THE L/S RATIOS
(MAJOR/MINOR MOVEMENTS)

Subject	Normal vs. Flight	Flight vs. Non-flight	Flight vs. combined normal and non-flight
1.	.637	1.312	.969
2.	1.075	.231	.506
3.	2.354	.557	1.289
4.	1.323	.144	.380
5.	.177	1.134	.735
6.	.359	.032	.259
7.	2.212	.309	.470
8.	2.289	3.221	.885
9.	.190	.457	.347
10.	.473	1.127	1.052
11.	.108	1.415	.938
12.	1.577	4.950	3.114

It can be seen from Table X that the only statistically significant differences are for Subjects 8 and 12 in the flight versus non-flight records and for Subject 12 in the flight versus the combined normal and non-flight records. For both subjects the proportion of minor movements increases on flight nights. It will be noted that on the normal versus flight records, Subjects 3 and 8 approach significance. Particular note should also be made of the large individual differences shown in the means for the normal conditions, ranging from .105 to .827 (Table IX).

<u>Correlations of major and minor indices with other indices.</u> Correlation coefficients were also computed between the L (major movement) index and the S (minor movement) index for all four conditions. The correlations proved to be small and negative, ranging from .17 to .56. Correlations were also computed between the one-minute motility index and the L and S indices. The r's between the L index and the one-minute motility index were all close to zero and unreliable. However, the correlations between the S index and the one-minute motility index were uniformly high and very reliable, ranging from .85 to .93. Apparently, then, counting the minor movements would provide nearly as good a picture of sleep motility as counting all movements.

Of interest also are the correlations computed between the L/S ratios and the one-minute motility indices. For the records taken on the normal nights the correlation proved to be .55; for the nights following flights it was .87; for the non-flight conditions, .83; and for the combined normal and non-flight conditions, .68. It thus appears that those subjects who stir about very little in their sleep tend to make larger movements when they do stir than those who are very active.

<u>Records for nights following critical maneuvers.</u> Inasmuch as there proved to be few reliable differences between the normal and flight night records as a whole, the possibility was investigated that larger differences might be revealed if the normal sleep records were studied in relation to those records taken on the nights following flight lessons in which "critical" maneuvers had been practiced.

The determination of what constituted a critical maneuver was somewhat arbitrary. However, after due consideration the following maneuvers were adjudged to be "critical" enough to fall in this category: the first three hops, the first stalls, the first solo flights, the first three flights after the solo, spins (both dual and solo), eights around pylons, and cross-country flights.

The average one-minute motility indices for nights following critical maneuvers (presented in Table XI) proved not to differ significantly from normal motility. (It will be recalled from Table II that three subjects showed significant differences between normal and "flight" records. For each of these subjects, differences are diminished when attention is focused upon nights following critical maneuvers.)

TABLE XI

MEANS OF ONE-MINUTE MOTILITY INDICES FOLLOWING CRITICAL MANEUVERS

Subject	Motility Index
1.	.160
2.	.149
3.	.126
4.	.136
5.	.137
6.	.080
7.	.158
8.	.166
9.	.146
10.	.089
11.	.102
12.	.141

Elimination of records involving less than six hours of sleep. In graphing the results it became apparent that much of the extreme variation appeared to be brought about by the inclusion of records for relatively short sleeping periods. Accordingly, new distributions were made in which no records involving less than six hours of sleep were included. The effect of the elimination of those records of short periods of sleep on the distributions is shown in Table XII. The variability is considerably reduced and certain of the differences are made more reliable. It is not clear as yet why short sleeping periods should tend to make the motility of the subject either very high or very low, but it is apparent that such is the result.

TABLE XII

ONE-MINUTE MOTILITY INDICES FOR RECORDS FOR SIX OR MORE HOURS SLEEP
(Means for 12 subjects)

Subject	Normal Nights	Flight Nights	Non-flight Nights	Normal and Non-flight (comb.)
1.	.146	.157	.159	.152
2.	.147	.144	.160	.153
3.	.138	.139	.148	.144
4.	.135	.133	.132	.133
5.	.141	.140	.136	.139
6.	.084	.082	.085	.084
7.	.171	.183	.181	.179
8.	.185	.166	.176	.179
9.	.158	.156	.155	.156
10.	.096	.092	.087	.090
11.	.088	.103	.110	.102
12.	.149	.163	.165	.159

SUMMARY AND CONCLUSIONS[7]

Records of the sleep motility of twelve students participating in the Civilian Pilot Training Program were obtained by means of the Johnson Sleep Motility Recorder (Simmons Kinetograph). Nightly records, representing 1156 "man-nights," were procured over a six-month period. An adequate sample of the "normal" sleep behavior of each student was procured prior to the beginning of his flight training. The records taken during the flight training were divided into two major types: those taken on nights following a flight lesson and those taken on non-flight nights. Further analyses were also made of those records of sleep motility following days on which "critical" maneuvers were practiced. Both the relative amounts of time spent in movement during sleep and the magnitude of the movements were studied.

In general, the results of the study were negative, i.e., according to these data, actual flight training has little effect on the sleep behavior of the subject. This general conclusion seems to hold regardless of whether the amount of time spent in movement or the magnitude of the movements are considered.

Various indices of sleep motility were considered and it was found that although the one-minute motility index (the ratio of the number of "active" one-minute periods of sleep and the total number of minutes spent in sleep) distorted the picture considerably, it was sufficiently closer to the actuality than was the five-minute motility index to justify its use. Correlations between the one- and the five-minute motility indices ranged from .73 to .84.

In the analysis of the one-minute motility indices for the four experimental conditions (normal nights, flight nights, non-flight nights, and the normal and non-flight nights combined) it was found that there was a significant change in the sleep behavior following flight of only three students (C. R. = 4.687 for Subject 7; 3.096 for Subject 11; and 3.634 for Subject 12). The analysis of the five-minute motility index for the same categories of records showed the sleep behavior to increase significantly following flight days in only one of the subjects (C. R. = 4.095 for Subject 11).

Analysis of the major (trunk) movement index (the L index) revealed that the proportion of major movements following flights increased significantly over normal nights in three of the subjects (Subjects 3, 7, and 11; C. R. = 3.465, 3.380, and 3.250 respectively), and decreased significantly in one (Subject 8; C. R. = 3.545). The change approached significance in Subjects 2 and 4 also (C. R. = 2.645 and 2.380). Subjects 3 and 12 also approached significance in the difference between flight and the non-flight nights (C. R. = 2.454 and 2.360). The same is true for Subjects 3 and 4 for the flight records versus the combined normal and non-flight records (C. R. = 2.525 and 2.500).

The results of the minor (limb and head) movement index (the S index) revealed no significant increases. However, here also Subjects 11 and 12 approached a significant change in normal versus flight night (C. R. = 2.811

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[7] Editor's note. The interpretation of the results of this study, particularly the interpretation of the critical ratios presented, is seriously handicapped by the fact that the number of records upon which each index is based is not given. Further, the exact methods of computing the number of "active minutes" and the magn. [illegible] indices are not presented.

and 2.432) and Subject 6 in the flight versus the combined normal and non-flight records (C. R. = 2.576). The correlations between the L index and the S index all proved to be small ranging from .17 to .56. The correlations between the L index and the one-minute motility index were all close to zero, while the corresponding r's for the S index ranged from .85 to .93.

Analysis of the L/S ratio revealed that Subjects 8 and 12 showed a significant increase in the proportion of minor movements on the flight nights over the non-flight nights (C. R. = 3.221 and 4.950) and Subject 12 also showed significant differences in the flight versus the combined normal and non-flight nights (C. R. = 3.114).

The average one-minute motility indices for nights following "critical" manouvers (Table XI) proved not to be significantly different from normal motility.

When records of less than six hours of sleep are excluded from the analysis the variability of the measures is greatly decreased. The reason for this is not clear at the present time.

FURTHER WORK

Future analysis of these records should take into account the following calculations:

1. A "movement time index," consisting of the total number of movements divided by the total minutes of sleep, should be computed for the various conditions. Likewise "minor movement time indices" and "major movement time indices" should be calculated.

2. Distributions of all indices, combining flight and non-flight nights in a single class, should be made.

3. The differences in all indices between the normal and combined flight and non-flight conditions should be determined, together with their reliabilities.

4. The following correlations should be computed:

   (a) Movement time index versus minute motility index.

   (b) Minor movement time index versus minute motility index.

   (c) Major movement time index versus minute motility index.

   (d) Minor movement time index versus major movement time index.

5. A rather more complete calibration of major and minor movements should be made, involving several subjects on different types of sleeping equipment. Possibly a study of this sort should be done photographically or at least supplemented by photographs.

6. All results should be subjected to a thorough graphical analysis to supplement the numerical one.