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ELECTROENCEPHALOGRAPHY OF NAVAL AVIATORS

by

ALEXANDER FORBES

and

HALLOWELL DAVIS

with a
Supplement

EEG Analysis of 79 Selected C.A.A. Subjects

by

Pauline A. Davis

A report on research conducted at The Naval Air Station, Pensacola, Florida, 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, in cooperation with the Bureau of Aeronautics of the U. S. Navy.

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LETTER OF TRANSMITTAL

NATIONAL RESEARCH COUNCIL

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

Committee on Selection and Training of Aircraft Pilots

April 6, 1943

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

Dear Dr. Brimhall:

The attached progress report, entitled Electroencephalography of Naval Aviators, by Alexander Forbes and Hallowell Davis, embodies results of an early investigation conducted at Pensacola Naval Air Station under a grant-in-aid from the Committee on Selection and Training of Aircraft Pilots. The report is submitted by the Committee with the recommendation that it be included in the series of technical reports issued by the Division of Research, Civil Aeronautics Administration.

Attached to the main report, as a Supplement, is a Progress Report, by Pauline A. Davis, entitled EEG Analysis of 79 Selected C.A.A. Subjects, which embodies material referred to in the paper by Dr. Forbes and Dr. Davis.

The results and conclusions in both papers must be considered as highly provisional, in part, because at the time the progress reports were prepared much still remained to be done in resolving problems in the interpretation of EEG records and in meeting experimental requirements for statistically determining the significance of data, for cross validation, etc. Nevertheless, it seems desirable to include these reports in the technical series, since they represent pioneering studies in the investigation of the possible usefulness of EEG in the selection of pilots.

Further analysis of the Pensacola data has been undertaken, and the results of this analysis, as well as results of other electroencephalographic studies sponsored by the Committee on Selection and Training of Aircraft Pilots, will be published in subsequent reports.

Very truly yours,

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

MSV:rm

EDITORIAL FOREWORD

Early in the history of the Committee on Selection and Training of Aircraft Pilots, it was suggested that electroencephalographic techniques might provide a means of eliminating from flight training those individuals possessing latent epileptoid trends and emotional instabilities not revealed by other forms of examination. Steps were therefore taken to include an examination of the EEG in the investigation of flight predictors undertaken at the Pensacola Naval Air Station in 1940, in cooperation with the U. S. Navy.

The following report represents a preliminary analysis of the data gathered in this investigation, submitted by the authors as a progress report. It seems desirable to publish this report as a chapter in the history of electroencephalographic research, including results of interest to those currently engaged in such research. Later reports on the Pensacola study will include a more extended analysis of the predictive efficiency of EEG.

There is also presented as Supplement I, a progress report on a related study by Pauline A. Davis, EEG Analysis of 79 Selected C.A.A. Subjects. This study, sponsored by the Committee on Selection and Training of Aircraft Pilots, was directed at determining the practicality of a 20-minute EEG measure in selecting military pilots.

CONTENTS

	Page
Editorial Foreword	v
Summary	ix
Introduction	1
The Problem	1
Procedure	1
Subjects	2
Methods of Analyzing Records	3
The Stability Scale	3
The Brazier Method of Scoring the EEG	4
The Forbes Modification of the Brazier Method	5
Criteria of Flight Performance	5
Results and Conclusions	6
Comment	15
Supplement I. EEG Analysis of 79 Selected C.A.A. Subjects, by Pauline A. Davis	17
Supplement II. Editor's Note: Preliminary Analysis of the Validity of the EEG as a Predictor	33

SUMMARY

The purpose of the present study was to determine the incidence of EEG patterns among cadets and trained aviators which were definitely suggestive of latent or undetected epilepsy; to define the degree of correlation between lesser degrees of electroencephalographic irregularity and failure in flight training; and to devise a practical empirical method of scoring.

EEGs were taken and analyzed for nearly 1000 cadets, student officers, and instructors at the Pensacola Naval Air Station. Four features of these records, (a) the frequency of the dominant rhythm, (b) unusually prominent episodes, (c) unusual prominence of fast-frequencies, and (d) unusual prominence of slow-frequencies, were analyzed by three different scoring systems: (1) a 13-point 'stability' scale (modified from the original 5-point scale of Davis), (2) the Brazier method, and (3) the Forbes modification of the Brazier scale.

The incidence of marked episodes in a group of 471 cadets and instructors was found to be 3%; of marked slow waves, 11%; and of marked fast-frequencies, 19%. Only one clearly abnormal record was found in the entire group tested. Elimination of records for those individuals who become drowsy during the tests did not materially affect this percentage incidence.

Calculations of the percentage expectancy of passing (corrected for the ratio of passers to failures for the entire base) revealed that no useful discrimination could be made between those who will succeed and those who will fail when the 'stability' scale method of scoring was used. Only the presence of unusually prominent fast-frequencies (expectancy of 86.3%) carried with it a prediction of less than average expectancy of success (90%) when the records are scored by this method. However, when the results of only those classes from 148-152 are used and the drowsy records eliminated, episodes, fast-frequencies, and slow frequencies all show less than average expectancy of success, 85.1, 84.2, and 84.1%, respectively.

When the percentage expectancy of passing was calculated for the scores on the Forbes modification of the Brazier scale it was found that a score of 12 or worse definitely indicated a diminishing expectancy of success in flight training. This scale is shown to be slightly superior to both the original stability scale and the Brazier method in terms of the percentage expectancy of passing for those in the failing group with adverse records and scores.

Scores on the Brazier-Forbes scale showed a -.194 correlation with Peckham's flight-score based on check and recheck flights, but the significance of this figure is doubtful since both distributions are extremely skewed.

The relation of EEG scores to the reasons given for failure in flight training confirms the impression that the 'bad' EEG indicates some 'psychological' or 'temperamental' traits that are unfavorable for aviators.

Trends are shown which indicate that the EEG could possibly serve in a selection battery to weed out a very small minority of potential failures. However, proof of the value of the EEG as a selection device awaits statistically significant results.

ELECTROENCEPHALOGRAPHY OF NAVAL AVIATORS

INTRODUCTION

The electroencephalogram (EEG) represents a composite picture of the action potentials generated by the activity of cortical cells and their synaptic interconnections. Certain of these patterns have been found to be fairly stable for normal, healthy individuals. Others of the patterns seem to deviate markedly from this characteristic picture indicating dysfunctioning of the nervous system.

One of the most distinctive and throughly investigated of these deviate patterns is found in individuals suffering from epilepsy or who have a history indicative of latent or undetected epilepsy. It has also been pointed out in a number of other studies that persons with unusual characteristics in temperament and emotional make-up tend to have distinctive patterns.

It seemed possible therefore that some of these abnormal patterns, particularly those most closely associated with latent epilepsy, if properly scored and interpreted, might correlate with success and failure in training for aviation by revealing favorable and unfavorable characteristics of the nervous system not readily assessed by other types of examinations.

THE PROBLEM

The purpose of the present investigation was; first, to determine the incidence among cadets and trained aviators of patterns definitely suggesting latent or undetected epilepsy; second, to determine the correlation between lesser degrees of the kind of irregularity and instability of the EEG pattern associated with epilepsy and difficulties or failure in training; and finally, to devise a purely empirical scoring system for the records which might prove of practical, predictive value.

PROCEDURE

The EEGs were taken essentially according to the procedure described by P. A. Davis under standard conditions (physical, and as far as possible, mental relaxation).[1]

Briefly: Electrical potentials were picked up by means of small electrodes attached externally over three different areas of the scalp -- the frontal, precentral, and occipital areas. These action potentials were taken off by three leads and greatly amplified. Their pattern was automatically recorded by a three-channel pen writer. Each record took approximately forty minutes to complete including time necessary to attach the electrodes.[2]

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[1]Davis, P. A. Technique and Evaluation of the Electroencephalogram. J. Neurophysiol., 1941, 4, 92-114.

[2]Professor Hudson Hoagland collaborated in obtaining these electroencephalograms but was unable to share in the preparation of this report.

As part of the original procedure, following routine recording of the electroencephalogram, each candidate was required to breathe deeply for a period of three minutes while his EEG was still being recorded.[3]

SUBJECTS

Nearly a thousand cadets, student officers, and instructors at Pensacola were included. Testing began July 15, 1940 and the apparatus was dismantled on April 25, 1941. It should be emphasized that only in the case of the first five flight classes (Nos. 147-151) did all the cadets in each class come to the laboratory for testing. Only one-half or less of the cadets, and none of the student officers were tested routinely in classes from 152 on. In the autumn, all candidates recommended for drop by the Advisory Board, and later, all those scheduled to appear before the Board, came in for a test, whether they had been studied before or not. Therefore, it is only from the first five classes (147-151) that the distributions of EEG findings for the total population were obtained. Subsequent data are nevertheless valid for comparing successful and unsuccessful candidates.

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[3]Such hyperventilation frequently precipitates diagnostic episodes of abnormal waves in patients subject to 'petit mal' forms of epilepsy, but no such cases appeared in the present study. Other types of slow waves did appear in many cases as a normal reaction, but their appearance showed no relation to flight performance. It is difficult to standardize the degree of hyperventilation and at the same time make certain that the blood-sugar level is not too low at the time of the test. (Standardization was actually attempted using a spirometer and instructing the candidate to inhale in time with a given signal. This tends to insure the same degree of hyperventilation in all subjects. The method is, however, cumbersome and not entirely satisfactory.)

It was not until after most of the cases had been recorded that the significance of low blood-sugar in relation to the effect of hyperventilation on the EEG was determined (Davis, H. and Wallace, W., Factors Affecting the Changes Produced in the EEG by Standardized Hyperventilation, from Dept. of Physiol., Harvard Med. School. Copy in Committee files. And Davis, P. A., EEG Analysis of 79 Selected C.A.A. Subjects, 1941, Progress Report to the National Research Council. See Supplement I). Therefore, no significance in this report was attached to alterations produced by hyperventilation. Some minor discrepancies between figures reported here and those presented in the preliminary report (The Selection of Naval Aviators, Pensacola Project, Progress Report, May 1941, 47-60) are due to the fact that in evaluating the records for the first report some weight was attached to the effects of hyperventilation. It is now believed that routine hyperventilation is quite as likely to prove misleading as it is to be helpful to anyone but a specifically trained and well informed observer, and its use is not recommended unless there is a clinical history suggestive of epilepsy.

METHODS OF ANALYZING RECORDS

Two judges (H. Davis and Mrs. E. N. Beresford) independently rated the first 475 records. Those cases in which there was disagreement were jointly reviewed and rescored. Ten separate features of the record were measured or estimated and then examined in relation to success or failure of the candidate to determine which of them gave most promise of having predictive value. The features which were found to be most promising in this preliminary study were:

1. Frequency of the dominant rhythm (alpha rhythms of 8-12.9 cycles per second).
2. Unusually prominent 'episodes,' i.e., abrupt, transient outbursts of rhythmic sequences of waves with frequencies either above or below the normal alpha range.
3. Unusual prominence (not necessarily episodal) of waves slower than 8 cycles per second.
4. Unusual prominence of waves faster than 13 cycles per second.

The latter two features (dysrhythmias) were revealed as interferences with the more common frequencies by waves of the frequencies specified, running irregularly through the record. (The distinction between episodes and dysrhythmias is a real one but is sometimes hard to draw. In many cases, marked dysrhythmia is apt to be correlated with episodal tendencies. An example of these two types of dysrhythmias is found in Fig. 1, U.S. 320.)

The Stability Scale. This scale represents a slight modification of the scale described by P. A. Davis, (op. cit.). The original Davis scale may be described briefly as a five-point scale ranging from 1, indicating the stablest and most smoothly functioning cerebral cortex, through 5, revealing abnormalities which suggest instability and a tendency to a broad class of disturbances which includes epileptic seizures and probably also a number of kindred conditions less clearly recognized. These latter conditions are sometimes called 'epileptoid' and sometimes 'psychomotor' equivalents.

This original five-point scale was subdivided in the 'stability scale' into 13 points to obtain finer differentiation. It now ranged from 1, the most normal and regular waves, through 5, the clearly abnormal or clinical variety, as follows: 1, 1+, 2-, 2, 2+, 3-, 3, 3+, 4-, 4, 4+, 5-, 5. (Note, that in this scale 2+ is worse not better than 2.)

The ratings of the two judges on this scale were identical, or within one or occasionally two points, in nearly all cases, and agreement was as good on the extremes of the scale as on the large middle group centering around 2 and 2-.

It was implicit in the derivation of this latter scale that it expressed the degree to which the records were judged to resemble the type of EEG characteristically found in epileptic patients. Unfavorable scores were given to records showing considerable irregularity, and particularly to those with episodes of waves of unusual frequencies, while the more favorable scores were given to records characterized by regularity and stability. Most of the EEG

patterns of the [illegible] group were [illegible] the orderly and stable types which have been found to have the highest incidence among healthy, well-balanced persons, although some records revealed the irregular patterns that are more or less like those associated with epilepsy. It must be stated at once, however, that <u>except for the two most extreme cases, no significant relation between ratings on this 'stability' scale and flight performance could be demonstrated</u>.

<u>The Brazier method of Scoring the EEG</u>. When late in 1941 it became evident that the original 'stability' rating was not yielding significant correlations with flight performance, Dr. M. A. B. Brazier developed another system of scoring for use in a study of the EEGs of candidates at the Squantum Elimination Base.[4] Two criteria entered this system, the first based on the frequency of the dominant rhythm, the second on the presence of other disturbing rhythms or episodes. The scale was so constructed that the most favorable rating was given to those individuals lying within 1 standard deviation (sigma) of the mean, empirically determined for a group of 100 candidates. The next step in the scale included those cases lying between 1 and 2 sigma from the mean, and the worst ratings were given to the small number that deviated most widely. No preconception as to resemblance to 'epileptic' patterns entered into the construction of this scale, but simply the principle of deviation from the mean for the group. In more detail, Dr. Brazier's criteria were as follows:

<u>Criterion No. 1</u>: Using only the occipital records during normal breathing, the frequency of the dominant rhythm was measured. The rating depended on how far this departed from the mean in terms of the standard deviation. Ratings 1 to 3 were based on the dominant rhythm, whether that was in the alpha (8 to 13 cycles) or in the beta (19 to 42 cycles) range.

<u>Rate 1</u>: Alpha dominant, with a frequency between 9.6 and 11.2 cycles; or beta dominant between 26 and 34 cycles (in each case, not over 1 sigma from the mean).

<u>Rate 2</u>: Alpha 8.8 to 9.5 or 11.3 to 12.0, or beta 22 to 25 or 35 to 38 (1 to 2 sigma).

<u>Rate 3</u>: Alpha 8.0 to 8.7 or 12.1 to 12.8, or beta 19 to 21 or 39 to 42 (2 to 3 sigma).

<u>Rate 4</u>: Cases in which frequencies from 12.9 to 18.9 were marked and of high voltage, even if not actually the dominant rhythm.

<u>Rate 5</u>: Dominant rhythm slower than 8 cycles.

<u>Criterion No. 2</u>: Now the records were rated for other distrubing rhythms (dysrhythmias and episodes) using the parietal or precentral and occipital readings under normal breathing conditions.

<u>Rate 1</u>: No waves between 14 and 17.5 cycles and none less than 7 cycles.

<u>Rate 2</u>: Waves of 14 to 17.5 cycles in trains of 3 or more successive waves, or any 6 cycle waves.

<u>Rate 3</u>: Scattered 4.5 to 5.5 cycle waves (dysrhthmia).

<u>Rate 4</u>: Trains of 4.5 to 5.5 cycle waves (episodes), or trains of high-voltage fast waves (faster than 14 cycles per second).

<u>Rate 5</u>: Presence of 2 to 4 cycle waves (delta waves).

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[4] This scale was used in the same manner as the previously mentioned 'stability' scale.

The Forbes Modification of the Brazier Method. In an effort to produce a single scale giving a wider spread of scores, one of the authors (AF) combined Brazier's criteria and supplemented them by other data believed to be significant by Drs. Thorner (Randolph Field) and Goodwin (Toronto). Thorner and Goodwin considered the dominant frequency more important than the disturbing rhythms, and Thorner believed that frequencies between 10.0 and 10.5 were more favorable than those in the rest of the band. He further believed that a wide spread in alpha frequency was a bad sign.[5] The following rules were therefore adopted:

1. Multiply by 2 the rating according to Brazier's first criterion (except when the dominant frequency is in the range of 10.0 to 10.5 cycles; this is counted as 0.);
2. Add the resulting figure to the rating for the second criterion.
3. If the spread of the alpha frequencies exceeds 1 cycle, add 1 point for every cycle or fraction of a cycle more than 1.
4. The sum of the three figures is the total score.
5. In the case of 'beta' records in which the dominant frequency is higher than 14 cycles, extent of spread is ignored, and 1 point is arbitrarily added.

It required 5 to 10 minutes to evaluate a record according to the Brazier-Forbes system of scoring. In this investigation, the Brazier method was applied to 123 of the Pensacola records selected at random, and the Forbes method to 265.[6]

CRITERIA OF FLIGHT PERFORMANCE

The criterion of performance employed in the Progress Report of May 1941 was primarily that a candidate had passed the course or had been dropped from training. A minor correction was applied in that candidates who were dropped because they were found to be 'not physically qualified' or for 'disciplinary' reasons were eliminated. The criterion was further refined by considering as intermediate groups, (a) those who appeared before the Advisory Board but were recommended by the board for extra time, and (b) those recommended to be dropped by the Board but who were granted extra time by the Commandant.[7] The 'intermediate group' is a category not used in the present report.

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[5] Editor's note. A wide spread in alpha frequency is considered a bad sign by some workers only if it exceeds certain absolute limits (8.5 and 12 cycles per second).

[6] It was impossible to extend further the application of the method because Dr. Forbes was ordered to Washington and a large number of the Pensacola records were transmitted to Dr. Goodwin in Toronto for him to study by his methods.

[7] Editor's note. If a cadet's flight training goes smoothly he does not come before the Commandant's Advisory Board. If he fails a number of flight checks or fails in ground school, he appears before the Board and his case is carefully considered. He may or may not be granted extra time by the Board. The Commandant then reviews the recommendations of the Board and makes the final decision. He may or may not take the Board's decision. This makes for four classes of cadets: (a) those who haven't come before the Board; (b) those granted extra time on recommendation of the Board; (c) those recommended for drop by the Board but given extra time by the Commandant; and (d) those dropped from flight training.

More complete data were later made available concerning the number of flight checks and rechecks flown by the students (see p. 12), and also concerning the reasons for which students were dropped from flight training (see p. 13). Many of the students who ceased training at their own request, those who were killed in accidents, those dropped for disciplinary reasons, and those dropped because they were not physically qualified to continue have been eliminated from the failure or 'wash-out' group in most parts of the present report. The 'success' and 'failure' groups thus conform to those used by other workers in treating data on the same Pensacola subjects. For supplementary comparisons, however, all of those eliminated from training were included since the student's own request to cease training may have been directly related to certain characteristics of his EEG or may have disguised other more significant reasons.

The Peckham Flight Score. As one kind of criterion, Dr. R. H. Peckham devised a flight score based on the number of possible flights and the number of rechecks as follows: There were 35 possible flight checks and rechecks in primary land planes, all of which may or may not have been flown. If a student passed his first check at each stage of flight training, he would have flown a total of five check flights and it was assumed that the remaining 30 checks would have been flown satisfactorily. If he failed the first two of his three checks at any stage, it was assumed that his third would also have been unsatisfactory. He could then be granted rechecks by the Squadron Board or rechecks by the Commandant's Advisory Board or by the Commandant himself. If a student was dropped for any reason, all checks following his stage of drop were regarded as unsatisfactory.

The flight score was then, 35 (possible checks) minus the number of checks actually flown or assumed flown unsatisfactorily, i.e., it was the number of flight checks actually flown or assumed to have been flown satisfactorily out of a possible 35.

RESULTS AND CONCLUSIONS

Abnormal EEG Records. The one record judged abnormal enough to be rated a 5- on the stability scale deserves special mention. This cadet, who had successfully completed a C.A.A. training course, was sent to the EEG laboratory by his instructor because of his extreme tendency to get airsick with frequent vomiting, and generally erratic performance. He would fly well on his tests and then slump suddenly in a way that led the instructor to conclude that he was dangerous. He also showed capricious psychology which his instructor called 'infantile.' Although he passed his solo check, he decided himself that he was not suited to naval aviation and was dropped at his own request. His EEG (see Fig. 1, U.S. 1160) showed episodes of high-voltage, low-frequency waves, at times closely resembling those of a petit mal epileptic seizure. There is little doubt that the episodes in his record showed abnormalities of brain function related to his difficulties in flight. In this case, had the record been taken in advance of his flight training and properly evaluated, it might well have justified his elimination.

The appearance of only one record indicating such a degree of abnormality among nearly 1,000 studied probably gives a fair indication of the rarity with which men with undetected or latent epilepsy pass the rigorous examination and

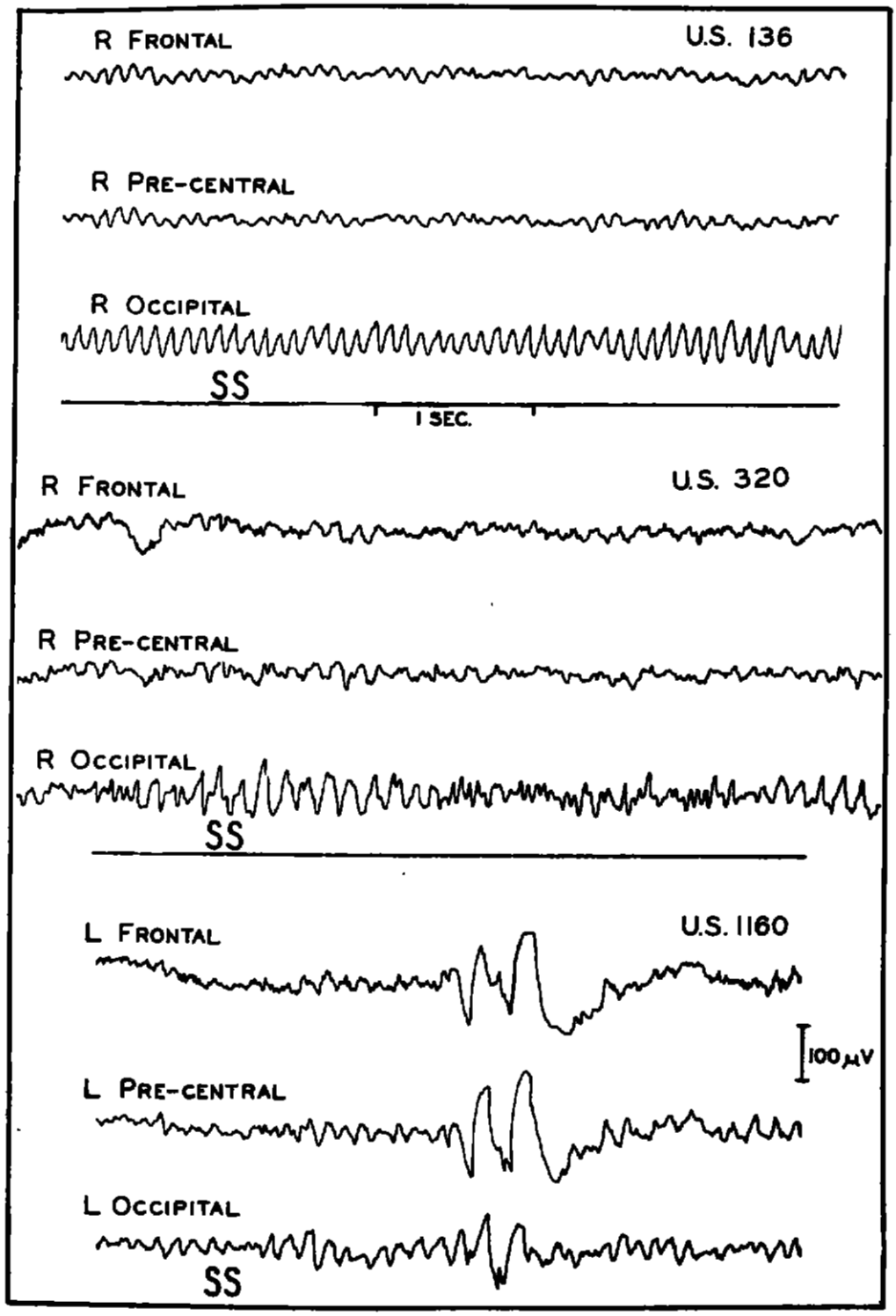

FIGURE 1

Sample Section of EEG'S of Three Pensacola Cadets

selection through which candidates must pass before they reach Pensacola. The fact that some cadets whose EEGs were rated near the danger point have passed the course raises the question of the significance of borderline degrees of 'abnormality.' Possibly their unstable EEGs carry with them a positive factor actually favoring success if the instability is not too extreme, or perhaps they may yet prove to be dangerous pilots in their subsequent careers. Their flight scores (Peckham's) give no indication of difficulty in learning to fly, but their future histories should be watched very closely.

Incidence of Special Features in the EEG.[8] The frequency-range of the usual dominant rhythm (the so-called alpha rhythm illustrated in the top record of Fig. 2, U.S. 136) was from about 8 cycles per second to about 13 per second, showing agreement with most other investigations of normal EEGs that have thus far been reported. Individuals differed considerably in the regularity of their alpha rhythms. In some it varied only a fraction of a cycle per second from one part of the record to another, while in others it varied by as much as 1 1/2 to 2 cycles. The most common frequencies for the group as a whole were those between 10 and 10.5 per second, again in agreement with other studies of the normal individual.

The incidence of unusually prominent 'episodes,' slow frequencies below 8 cycles per second, and fast frequencies above 14 per second were studied in classes in which all the cadets were given tests (classes 147-151) and in 94 instructors. All three of these features, episodes, fast, and slow waves, were scored on the same five-point scale as follows: -- (absent), ± (doubtful), + (definitely present), ++ (marked), +++ (very marked).

These percentages constitute an implicit definition of what is meant by an unusual degree of prominence. The amount of fast-frequency activity considered 'unusually prominent' (scored as ++ or +++ on this scale) was the amount found in about one case out of five in such a group of presumably normal young men such as was studied here; 'unusually prominent' slow frequencies (scored as ++ or +++ on the same scale) are the sort of slow waves observed in one out of eight or nine records of these men, and so forth (Table I).

TABLE I
Percentage Incidence of Special EEG Features

	No. EEGs	Episodes(++) No.	Episodes(++) %	Slow Waves(++) No.	Slow Waves(++) %	Fast Waves(++) No.	Fast Waves(++) %
Cadets	377	10	2.7	46	11.9	73	19.4
Instructors	94	4	4.2	9	9.6	16	17.0
Cadets minus 'drowsy records'	311	9	2.9	37	11.9	59	18.9

[8]Presented in Fig. 1 are sample sections of EEGs of 3 Pensacola cadets. Top (U.S. 136) is a normal stable record; candidate successful. Middle (U.S. 320) is an irregular, unstable record with frequencies faster and slower than the alpha rhythm; both prominent; candidate failed. Bottom record (U.S. 1160) is abnormal; the worst in the series; presumptive evidence of an epileptoid condition; candidate failed. (S8 means standard sensitivity, as shown in calibration.)

TABLE II

EXPECTANCY OF SUCCESS IN RELATION TO SPECIAL FEATURES OF EEG

Entire group except for "drops not counted as wash-outs"

	Total EEG	Episodes (++)	Slow (++)	Fast (++)	Rating of 3+ or worse
A. Successes studied	721	39	94	155	58
B. Failures studied	126	6	14	39	9
C. Successes corrected to 90 per cent pass rate	1134	61	148	244	91
D. Corrected totals, i.e., B + C	1260	67	162	283	100
Per cent expectancy of passing, i.e., C/D	90.0	91.0	91.4	86.3	91

Classes 143-152 Calculated Separately

	Total EEG	Episodes (++)	Slow (++)	Fast (++)	Rating of 3+ or worse
A. Successes studied	289	5	31	55	21
B. Failures studied	37	1	8	12	4
C. Successes corrected to 90 per cent pass rate	333	6	36	63	24
D. Corrected totals, i.e., B + C	370	7	44	75	28
Per cent expectancy of passing, i.e., C/D	90.0	85.8	81.9	84.0	85.7

In spite of precautions taken, a considerable number of the cadets became drowsy during the EEG tests. The usual alterations, particularly a reduction in the amount of alpha rhythm, and the appearance, often in episodes, of slow waves in the precentral and frontal regions, were subsequently identified in the records.[9] Apparently the effects of drowsiness were successfully accounted for by the judgment of the significance of episodal, slow, and fast waves, for when the records suspected of drowsiness were eliminated the percentages of these three features remained virtually unchanged. (See last line Table I.)

Percent Expectancy of Passing Based on Various EEG Criteria. A convenient method of expressing the predictive value of the various EEG criteria was devised in terms of the percentage expectancy of success. The average percentage of success of all candidates at Pensacola over the period during which the EEG records were taken was about 90%. All of the successful candidates at Pensacola were not studied in this investigation however. Therefore, when arbitrary numbers of successful and unsuccessful men were to be compared, it was necessary to increase the number in the passing group to give the known passing rate of 90%. To accomplish this increase, the number of passers studied was multiplied by the following factor:

$$\frac{\text{failures studied} \times \text{assumed ratio of pass to fail, i.e., 9:1}}{\text{successes studied}}$$

The percentage of men with a given EEG score who could expect to pass was then calculated according to the procedure indicated in Table II: (The successes studied were corrected to a 90% passing rate. This new figure for the passers was then added to the actual number of failures studied to yield a corrected total. The percentage expectancy of passing was now equal to the number of corrected successes divided by the corrected total.) In this way the percentage expectancy of passing was calculated for the men with unusual (supposedly unfavorable) features in their EEG, e.g. episodes, slow waves, fast waves, or a stability scale rating of 3- or worse.

From Table II (last line) it can be shown that only the presence of unusually fast frequencies (expectancy 86.3%) carries with it a prediction of less than average expectancy of success.

To determine the consistency of this result the same expectancies were calculated for classes 148-152 separately. Results from these classes were more reliable since (a) these classes were more completely studied than the others, (b) the majority of the records were obtained by experienced operators, and (c) our techniques had been established while studying class 147. The results from this group (148-152) were somewhat more encouraging than those of the total group. (See Table II.)

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[9] It must be emphasized that care has to be taken in judging EEGs not to confuse the normal slow waves of drowsiness with slow waves appearing in the fully wakened state, which may have a very different significance. As a matter of practical procedure, it is helpful to talk to the subject and instruct him to move about on the cot and kick his legs in the air from time to time during the intervals in the EEG routine. The subsequent evaluation of records in which this was done was far easier than for many of those in which it was not. (Care must be taken if this procedure is used to see that the electrodes are not disturbed or the records lost entirely.)

TABLE III

EXPECTANCY OF SUCCESS IN RELATION TO SPECIAL FEATURES OF EEG: CORRECTED FOR POSSIBLE DROWSINESS

Entire group except for "drops not counted as wash-outs"

	Total EEG	Episodes (+r)	Slow (+t)	Fast (+t)	Rating of 3+ or worse
A. Successes studied	569	23	59	128	48
B. Failures studied	93	4	11	29	5
C. Successes corrected to 90 per cent pass rate	832	36	91	225	64
D. Corrected totals, i.e., B + C	980	40	102	254	69
Per cent expectancy of passing, i.e., C/D	90.0	90	89.2	88.6	92.8

Classes 148-152 Calculated Separately

	Total EEG	Episodes (+r)	Slow (+t)	Fast (+t)	Rating of 3+ or worse
A. Successes studied	243	5	26	46	20
B. Failures studied	31	1	6	10	2
C. Successes corrected to 90 per cent pass rate	279	5.7	30	53	23
D. Corrected totals, i.e., B + C	310	6.7	36	63	25
Per cent expectancy of passing, i.e., C/D	90.0	85.1	84.2	84.1	92

suggested [illegible] (The [illegible] drowsiness had been made before the results of this study were known to the experimenters.) As can be seen the results were not materially altered for the entire group or for classes 143-152 by the elimination of these records. The only consistent result was the indication that the presence of very prominent fast-frequency waves in the EEG was an unfavorable sign. The lack of consistency in respect to episodes and slow waves is still without explanation.[10] (See Table III.)

Expectancies by the Brazier-Forbes Method. To determine the significance of the Brazier-Forbes scale and the best dividing line for predictive purposes, 202 successes and 63 failures were selected at random from the general groups of successful and unsuccessful candidates (see p. 5) and their distributions plotted according to the percentage of each group receiving each Brazier-Forbes score. A greater percentage of failures received 'bad' scores and a smaller percentage received 'good' scores in comparison with the passing group. The most favorable cut-off point for this scale seemed to fall between scores 11 and 12. (See Fig. 4.)

The expectancies of passing were calculated for various score-intervals in the Brazier-Forbes scale. These are presented in Table IV for the total group (N = 265) and the group after the drowsy records were eliminated (N = 221).

TABLE IV
Expectancies of Passing at Various Brazier-Forbes Scale Scores

Brazier-Forbes Score	% Expec. for total group (N = 265)	% Expec. drowsy rec. eliminated (N = 221)
1 - 4	92.8	92.0
5 - 7	92.3	92.0
8 - 18	83.7	85.5
8 - 11	88.0	90.7
12 - 18	64.7	63.9

These data also indicate that a score of 12 or worse definitely indicated a diminishing expectancy of success in flight training. Furthermore, moderate degrees of drowsiness did not seriously affect the scoring of the records by this method, at least in the hands of an experienced electroencephalographer.

Comparison of the Brazier-Forbes Method with the Stability Scale. To determine whether the superiority of the Brazier-Forbes method over the original method depended on a fortunate selection of records, the expectancy of passing for the same group (drowsy records eliminated -- N = 221) was calculated for scores derived by the original method. It was found that the percent expectancy of passing was 93% for episodes (+-); 93.7% for the slow

[10] These features are reported by Drs. Thorner and Goodwin, in a personal communication, to have some predictive value.

frequencies (++); 87.9% for the fast frequencies (++); and 95.5% for those records scored 3+ or worse. The expectancy by the Brazier-Forbes scoring system at score-interval 12-18 (see Table IV) was 63.9%.

The low expectancy of passing by the Brazier-Forbes method was all the more striking in view of the high expectancies for this group when the previous method of scoring was used.

Comparison of the Brazier-Forbes Method with the Brazier Method of Scoring. The Brazier method is simpler than the Forbes modification, and, if equally successful, would therefore be preferable in practice. The expectancies of passing were therefore calculated for 85 records (drowsy records excluded) studied by Dr. Brazier and later re-scored by the Brazier-Forbes method. The series included 39 failures, 11 of whom were given unsatisfactory scores (12 or worse) by the Brazier-Forbes method and 12 by the Brazier method (rating 4 or 5 on one or both criteria). In other words, 23% and 31% of the failures were correctly identified by the two methods. In percentage expectancy, however, the Brazier-Forbes modification was superior, as it rated as unsatisfactory only 3 records out of those belonging to the 46 successful candidates, against 6 so rated by the Brazier method. The expectancy of passing for those rated as 'unsatisfactory' (corrected to 90% passing rate) was therefore 79% by the Brazier method, as against 67.8% for the Brazier-Forbes modification.

The superiority of the Brazier-Forbes method seemed to lie primarily in a better discrimination, and therefore less wastage of good men if it were used as a criterion for selection. If conclusions may be drawn from this small group, the Brazier-Forbes method is better than the Brazier system and far superior to the original method. On the other hand the success of both the Brazier-Forbes and the Brazier methods rested upon the correct selection of only about a dozen failures, and it is obviously important to re-test the method on a large and different group of additional candidates.

Analysis on the Basis of the Successful Indicators. This analysis showed a single feature of the EEG common to all three, namely "the presence of marked and high-voltage frequencies from 12.9 to 18.9 cycles" (Brazier's fourth item under criterion 1). This feature accounted for 8 of the 12 or more points in the scores of nearly all of the failures correctly selected by the Brazier-Forbes method. Obviously this feature is included in the broader designation of "unusually prominent fast frequencies" which was the one to show some consistent degree of accuracy in the original scoring. This band of frequencies lay between the familiar alpha (8.0-12.9 cycles per second) and beta (19-42 cycles) frequencies, which usually constitute the dominant rhythms. Only a few failures were correctly identified primarily on the basis of prominent slow frequencies or irregularity and instability of the total pattern which, on the basis of the earlier experiences with 'abnormal' EEGs, had been given particular weight in the original scoring method.

Analysis on the Basis of Peckham's Flight-Score. Very few of the candidates who failed attained a flight score above 23 and no candidate with a score below 23 passed. A correlation was calculated for the relation between flight-score (high score favorable) and the EEG score as derived by the Forbes modification of the Brazier scale (high score unfavorable). This correlation, - .194, although small, is of the proper sign. The exact significance of this correla-

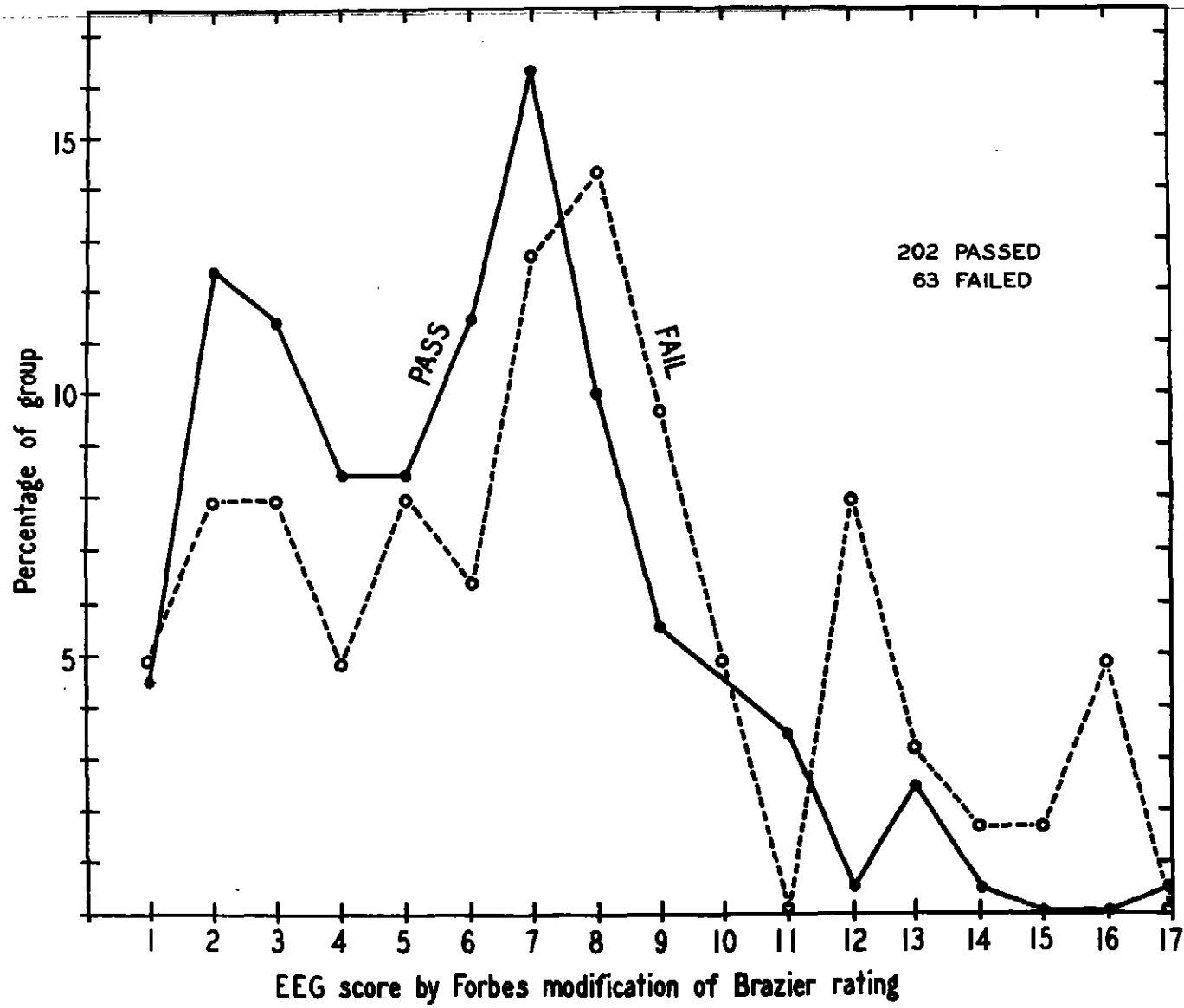

FIGURE 2

A Comparison of passing and failing groups in terms of the Forbes modification of the Brazier rating method.

[illegible] score [illegible]

The [illegible] for [illegible], with a [illegible] flight [illegible] and for [illegible] were as follows:

Flight-score	35	34	33	32	31	30	29	28	27-23	Dropped
No. of Men	32	21	17	33	33	16	21	19	10	63
Ave. B-F Score	5.7	6.3	5.4	5.3	5.9	6.9	6.8	4.8	5.8	7.4

Relation of EEG to Reasons for Failure in Flight Training. It need not concern us greatly that many wash-outs show good EEG scores, as there are many reasons for failure and it was unreasonable to expect that the EEG would be strongly correlated with many of them. More disconcerting were the excellent flight scores (34-35) made by three men who scored 13, 14, and 17 on their EEGs. No explanations are offered for this situation, but it was in accord with the experience of Drs. Goodwin and Thorner that, although the expectancy of passing was low for candidates with 'bad' EEGs, those who did pass flight training tended to be better than average aviators.[11]

The relation of EEG scores to the reasons given for failure confirmed the earlier impression that the 'bad' EEG indicated some 'psychological' or 'temperamental' traits that were unfavorable for aviation. From the flight-jackets for each man dropped, Dr. Peckham supplied one or more (usually two) of twelve possible reasons for failure (See list in Table V).

For the present analysis those killed in accidents and those dropped for disciplinary reasons were grouped together, as the numbers in these groups were small. Also, men dropped from training but not counted as 'wash-outs' were included in this analysis. The number of men for whom a given reason was stated (whether or not it was the sole reason) was totaled, and the percentage of each group that showed prominent fast (F++) or slow (S++) frequencies by the 'stability scale' scoring was calculated. The percentage of each group receiving a score of 3 or worse by the Brazier-Forbes method was also calculated. Finally, the percentages of incidence of the 'unfavorable' EEGs by the two methods were averaged (last column, Table V). (The reasons are listed in the order of these average percentages.)

It should be noted that the incidence of 'unfavorable' EEGs in the entire population was about 30% for each method, and that the average incidence among the 'not physically qualified' (N.P.Q.) was 29%. All other reasons showed a greater incidence, which was well above chance expectation for many of them. The rank order was an interesting confirmation of the expectation that the EEG would indicate failure for 'temperamental' or 'psychological' reasons rather than because of physical handicap, poor motor coordination, or lack of intelligence. The possible exception, adverse physical reactions, was based on a small number of cases. However, it was quite strongly correlated with prominent slow waves, and may well be related to the EEG at the neurological rather than at the psychological level.

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11. Editor's note. This observation is not in accord with recent findings in a study of 100 fliers at Randolph Field (Thorner, M., Gibbs, F. A., and Gibbs, E. L. Relation Between the Electroencephalogram and Flying Ability. War Med., 1942, 2, 255-262). Here the incidence of poor aviators among those with abnormal records was much higher than among the men with normal records. Among men who washed out in secondary training there was a great excess of abnormal records.

TABLE V

	Reason given for failure	Original: No. times reason given	Original: Per Cent having S++ or F++	Brazier-Forbes: No. times reason given	Brazier-Forbes: Per Cent scored 8-17	Avé. per cent B-F and orig.
OR	Own request	15	53	12	58	55.5
P	Adverse physical reactions, airsickness or illness	7	43	6	67	55.0
F	Psychologically unsuited. Excessive fear or obsessions	9	56	8	50	53.0
J	Poor judgment of speed, altitude, or distance	21	43	13	54	48.5
E	Excessive nervousness, tenseness, or anxiety	27	44	17	47	45.5
T	Temperamentally unsuited. Poor motivation, drive, responsibility, confidence, cooperation, or adjustment to service	26	35	15	53	44.0
I	General inaptitude in flying, not specifically described	54	39	27	44	41.5
M	Poor, slow, or unretentive learning or headwork in air or ground school	47	32	19	47	39.5
K and D	K= killed; D= Discipline, marriage, etc.	13	15	5	60	37.5
C	Poor coordination or control	22	45	13	23	34.0
NPQ	Not physically qualified to continue by Bur. Med. and Surg.	12	25	3	33	29.0
	Total number of reasons given	253		138		
	No. of men failing	156		63		
	Incidence in entire population		30%		29%	29.5%

[illegible]

[illegible] selected population, such [illegible] representing [illegible] training at the Elimination Bases. [illegible] seen that in spite of the disappointing results obtained by the original [illegible] of analysis, the results with the Brazier-Forbes method warrant vigorous continuation of EEG studies in relation to the problem of selection of aviators. The method should be applied to a large group of not too highly selected candidates. The method of scoring is still new and obviously capable of much greater empirical refinement. At least it seems that a significant guiding principle for the construction of a satisfactory scoring system has been demonstrated.[12]

The more strictly medical problem of the incidence of undetected epilepsy has been at least partly answered. The condition proved to be very rare among the Pensacola cadets. Nevertheless, electroencephalography has a place in the study of obscure cases in which the clinical evidence is not clear, - and if the EEG becomes established as one of a battery of routine selective tests it would also serve to call attention to some actual or potential epileptics who should be scrutinized with particular care from the clinical point of view.

In considering the place of the EEG in a battery of selective tests some weight should be given to our indication that the EEG seems to indicate "psychological" or "temperamental" reasons for failure rather than inadequate motor coordination, lack of intelligence, or general ineptitude.

The suggestion offered in our preliminary report that the EEG may prove still more useful in the problem of differential selection for different types of service, such as bomber *versus* fighter is still pertinent.

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[12]Editor's note. Before extensive use is made of this method it will need to be shown that it is a better technique than other methods of scoring already known to yield positive results. Further, new techniques have arisen since the inception of this study which also show promise.

SUPPLEMENT I

The following report presents a related study by Davis, P. A., E.E.G. Analysis of 79 Selected C.A.A. Subjects, submitted as an Interim Progress Report to the National Research Council Committee on Selection and Training of Aircraft Pilots.

Report To The National Research Council

E.E.G. ANALYSIS OF 79 SELECTED C.A.A. SUBJECTS

By Pauline A. Davis

PROBLEM:

This study was undertaken to discover whether a twenty minute E.E.G. taken under standard conditions might aid in the selection of candidates for service in the air forces. It is understood that approximately half of this selected group have failed and that the other half have passed the C.A.A. requirements. With no information whatsoever concerning these subjects, the routine E.E.G.'s were analyzed. The records were separated into normal and abnormal groups in order to determine the significance of certain factors in the E.E.G. and their possible relation to the subject's success or failure.

PROCEDURE:

A group of selected C.A.A. subjects were sent to the laboratory for a routine E.E.G. taken under standard conditions. Twenty minutes to one-half hour before the record was begun, each subject was given by mouth 50 c.c. Red Label Karo Corn Syrup in an equal amount of water to avoid too low a blood sugar level.[1] The E.E.G.'s and analyses were made according to the standards and rules set forth in the paper on "The Technique and Measurement of the Electroencephalogram," by P. A. Davis (Jour. Neurophysiol. Jan. 1941.)

The twenty minute routine record included the simultaneous recording from three different areas of the head, the Frontal, the Precentral, and the Occipital, as well as the simultaneous recording from left, right, and mid-line region of each area. Both monopolar and bipolar technic, and three different degrees of amplification were used for the purpose of bringing out detail. This is essential in low-voltage records.

A record run before, during, and after three minutes of hyperventilation was continued until the E.E.G. returned to the characteristics seen in the routine record. (The type of hyperventilation procedure was standardized by Dr. Ashton Graybiel.)

ANALYSES:

1. The routine records were analyzed by two judges independently,

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[1] "Effect on the E.E.G. of Changing the Blood Sugar Level" P.A. Davis, given before Amer. Physiol. Soc. April 1941 (sent to press).

then by both together, and a rating was agreed upon for each record.

2. The analyses were repeated independently at a later date without reference to the previous ratings. The consistency of the ratings was satisfactory.

3. The hyperventilation record alone was rated by one of us, without reference to the routine record.

4. The total record, routine and hyperventilation response, were then studied as a whole and again rated independently of the findings of the other analyses.

5. The specific features of the E.E.G. were then studied separately. The relation of the special features to the types and ratings are presented in tabular form so that the possible significance of any special feature may be tested and to facilitate comparison with the analyses of E.E.G.'s by other investigators.

COMMENT:

Tables 1 and 2: The subjects were rated first on a five-point scale and then on a three-point scale. The divisions were made into normal, borderline, and abnormal categories on the basis of the routine E.E.G. ratings. The ratings of the hyperventilation records were added for comparison with the routine rating in order to reveal the fact that a subject's response to a stress situation may or may not reinforce the routine rating.

The E.E.G. response to hyperventilation is variable. Many of the difficulties are due to the assumption that all subjects are equally intelligent and cooperative in regard to the requirements of the procedure. The apprehensive or tense subject may not hyperventilate adequately in spite of his efforts to cooperate. Another subject may unconsciously decrease his rate of respiration when he feels dizzy. An athletic subject, on the other hand, may hyperventilate so efficiently that delta activity will develop within the first minute causing his record to be considered abnormal. An abnormal subject, from whose routine E.E.G. one would predict an abnormal response to hyperventilation, often will either refuse or be unable to carry out the procedure for three minutes.

Certain types of E.E.G. patterns are normally more resistant to the development of delta activity than other types of patterns, regardless of the efficiency of the subject in carrying out the procedure. In the 1940 series of subjects recorded at Pensacola, and several hundred undergraduate students recorded at Harvard, it was found that delta activity would develop more readily when the subject was permitted to breathe freely than when he was attached to a spirometer. The E.E.G. responses nevertheless were recorded, measured, rated and plotted. It is believed, however, that reliance on the hyperventilation record alone should not be used in evaluating the normality of the subjects in this series.

The C.A.A. subjects appear to be distributed as follows:

Normal E.E.G.s - 38
Borderline E.E.G.s - 17
Abnormal E.E.G.s - 24

Five E.E.G.s in the normal group developed abnormal activity in response to hyperventilation. Eight E.E.G.s rated as abnormal in the routine record showed normal activity in the hyperventilation record.

Table 3: A and MF patterns are predominantly rated as normal.
B patterns show a wide distribution of ratings.
M and MS patterns fall largely in the borderline or abnormal classifications.

Table 4: The MF and B types of E.E.G. pattern show fewer 'abnormal' responses to hyperventilation than the A, M, and MS patterns.

Table 5: The alpha frequency represents the peak of the distribution of a minimum of twenty measurements of each E.E.G. counted in sections of the record at least 10 seconds after any response to stimulation. The reason for this is because of the known momentary acceleration in the frequency rate when the eyes are opened and then closed. A count in such a section would not be representative of the E.E.G. routine record. The alpha frequency is not clearly related to the rating of 'normality' and 'abnormality'.

Table 6: The alpha frequency is one of the features that distinguishes the A and MS types from the B and MF types.

Table 7: A division of the E.E.G.s into three main groups on the basis of dominant characteristics of the total record show that these E.E.G.s in which the alpha activity is the dominant feature, appear to be the most normal, and that those in which there is a continuous interplay of slow and fast activity, within a narrow frequency range are regarded as less normal. Low voltage is considered to be consistent with normality.

Table 8: The distribution of the patterns in Groups 1, 2, and 3 is clear. From the published definitions of the types of patterns this distribution should be expected.

Table 9: A list has been made of the code #, rating, types of pattern, alpha frequency and group classification in order to discover whether there may be a gross correlation among these several factors, and those measurements and findings from other tests which aided in qualifying these subjects as pilots.

TABLE I

FINAL ROUTINE E.E.G. RATINGS AND HYPERVENTILATION RESPONSE RATINGS

Five-Point Scale
79 C.A.A. Subjects
77 Subjects Hyperventilated

RATING 1		RATING 2		RATING 3		RATING 4		RATING 5	
AV#	HYP.R.	AV#	HYP.R.	AV#	HYP.R.	AV#	HYP.R.	AV#	HYP.R.
4	1	11	4	9	5	6	5	5	5
20	3	17	5	12	1	7	5	10	5
24	1	18	3	13	1	8	5		
33	1	29	1	14	4	15	5		
35	1	37	2	25	3	16	5		
40	3	38	1	27	1	19	1		
41	1	43	1	28	4	21	4		
42	2	45	3	32	3	22	4		
44	1	47	5	34	1	23	4		
54	1	48	1	46	1	26	1		
55	1	52	1	50	3	30	4		
56	1	60	3	51	3	31	5		
59	1	61	1	53	4	36	1		
65	1	67	1	58	1	39	not done		
69	5	70	3	64	4	49	5		
75	4	71	1	73	1	57	1		
		72	1	81	1	62	1		
		76	1			63	1		
		77	1			66	4		
		78	1			68	2		
		79	not done			74	1		
		80	1			82	5		
Total:	16	Total:	22	Total:	17	Total:	22	Total:	2

NUMERICAL DISTRIBUTION

Routine Rating		1	2	3	4	5	
Hyp.Rating	1	11	13	8	7	0	= 39
	2	1	1	0	1	0	= 3
	3	2	4	4	0	0	= 10
	4	1	1	4	5	0	= 11
	5	1	2	1	8	2	= 14
		16	21	17	21	2	= 79 (n + 1)

TABLE 2

ROUTINE E.E.G. RATINGS AND HYPERVENTILATION RESPONSE RATINGS

Three-Point Scale

N-Normal-----includes ratings of 1 and 2
B-Borderline- " " " 3
Ab-Abnormal-- " " " 4

NORMAL GROUP		BORDERLINE GROUP		ABNORMAL GROUP	
AV#	HYP.R.	AV#	HYP.R.	AV#	HYP.R.
4	N	9	Ab	5	Ab
11	Ab	12	N	6	Ab
17	Ab	13	N	7	Ab
18	B	14	Ab	8	Ab
20	B	25	B	10	Ab
24	N	27	N	15	Ab
29	N	28	Ab	16	Ab
33	N	32	B	19	N
35	N	34	N	21	Ab
37	N	46	N	22	Ab
38	N	50	B	23	Ab
40	B	51	B	26	N
41	N	53	Ab	30	Ab
42	N	58	N	31	Ab
44	N	64	Ab	36	N
45	B	73	N	39	not done
47	Ab	81	N	49	Ab
48	N			57	N
52	N			62	N
54	N			63	N
55	N			66	Ab
56	N			68	N
59	N			74	N
60	B			82	Ab
61	N				
65	N				
67	N				
69	Ab				
70	B				
71	N				
72	N				
75	Ab				
76	N				
77	N				
78	N				
79	not done				
80	N				
Total: 38		Total: 17		Total: 24	
Hyp.R. --6=B 5=Ab		Hyp.R.--8=N 5=Ab		Hyp.R.--8=N 0=B	

TABLE 3

TYPE OF E.E.G. PATTERN AND ROUTINE RATING

Distribution by subject's code #

	A	MF	M	MS	B
Rating 1	20 44 24 55 33 69 41 75 42	4 35 56 65			40 54 59
2	17 43 29 61 43 70	47 77 60 78 67 79 71	52 72 80	37 38	11 18 45 76
3	50	27 51	9 53 14 58 28 64 34	12 46	13 73 25 81 32
4	8 21 31	6 39 7 68 23 74 36	19 57 30 66 49	15 63 22 82 26	16 62
5	5 10				

NUMERICAL DISTRIBUTION

	A	MF	M	MS	B	
Rating 1	9	4	-	-	3	= 16
2	6	7	3	2	4	= 22
3	1	2	7	2	5	= 17
4	3	7	5	5	2	= 22
5	2	-	-	-	-	= 2
	21	20	15	9	14	= 79 (Total)

TABLE 4

TYPE OF E.E.G. PATTERN AND HYPERVENTILATION RESPONSE RATING

Distribution by subject's code #

	A	MF	M	MS	B
Rating 1	24 48 29 55 33 61 41 43 44	4 67 27 71 35 74 36 77 56 78 65	19 80 34 52 57 58 72	12 26 38 46 63	13 81 54 59 62 73 76
2	42	68		37	
3	20 50 70	51 60			18 40 25 45 32
4	21 75	23	14 53 28 64 30 66	22	11
5	5 17 8 31 10 69	6 7 47	9 49	15 32	16

NUMERICAL DISTRIBUTION

	A	MF	M	MS	B	
Reting 1	9	11	7	5	7	= 39
2	1	1	-	1	-	= 3
3	3	2	-	-	5	= 10
4	2	1	6	1	1	= 11
5	6	3	2	2	1	= 14
	21	18	15	9	14	= 79 (Total)

Distribution by subjects and [illegible]

Occ. a	Freq.	8.5-9	9-9.5	9.5-10	10	10.5-11	11-11.5	11.5-12	12	13
Rating	1			20 38 41 42	4 [illegible] 24 65 44 69 55 75		35 54 59	[illegible]		
	2		17	37	18 [illegible] 23 61 33 70 43 72 49 80	78 79	11 57 71 76 77	[illegible]	47	45
	3		48 53	12	14 51 25 58 50 [illegible]	9 73	13 [illegible] [illegible] [illegible]	26		27
	4	15 21	20	49 62	8 [illegible] 19 67 22 69 58	62	10 25 39 60 68 74	6 7 36		
	5			5		10				

NUMERICAL DISTRIBUTION

Occ. a	Freq.	8.5-9	9-9.5	9.5-10	10	10.5-11	11-11.5	11.5-12	12	13	
Rating	1	0	0	4	8	0	5	1	0	0	= 16
	2	0	1	1	10	2	5	1	1	1	= 22
	3	0	2	1	6	2	4	1	0	1	= 17
	4	2	1	2	7	1	6	0	3	0	= 22
	5	0	0	1	0	1	0	0	0	0	= 2
		2	4	9	31	6	18	3	4	2	= 79 (Total)

TABLE 6

OCCIPITAL ~ FREQUENCY AND TYPE OF E.E.G. PATTERN

Distribution by subject's code #

Occ. α Freq	8.5-9	9-9.5	9.5-10	10	10.5-11	11-11.5	11.5-12	12	13
E.E.G. Pattern									
A	21	17	5	8 44 69	10				
			30	34 48 70					
			33	29 50 75					
			41	31 55					
			42	43 61					
MF				4	78	25 68	60	6	27
				51	79	35 71		7	
				56		39 74		36	
				65		67 77		47	
M		58	49	14 52 64	9	34	28		
				19 53 72		66			
				30 57 80					
MS	15	26	12	22					
		46	37	38					
			82	63					
B				18	62	11 54	40		45
				25	73	33 59			
						16 76			
						32 81			

NUMERICAL DISTRIBUTION

Occ. α Freq.	8.5-9	9-9.5	9.5-10	10	10.5-11	11-11.5	11.5-12	12	13	
E.E.G. Pattern A	1	1	5	13	1	0	0	0	0	= 21
MF	0	0	0	4	2	8	1	4	1	= 20
M	0	1	1	9	1	2	1	0	0	= 15
MS	1	2	3	5	0	0	0	0	0	= 9
B	0	1	0	4	2	8	1	0	1	= 14
	2	4	9	31	6	18	3	4	2	= 79

TABLE 7

DISTRIBUTION OF E.E.G.S INTO 3 MAIN GROUPS

RELATION OF TYPE OF PATTERN TO GROUP 1, 2 and 3

Group 1: Alpha activity is dominant feature.
2: Dysrhythmic quality is dominant feature.
3: Low voltage is dominant feature.

Distribution by subject's code #

Group	1	2	3
E.E.G. Pattern A	5 24 48	31	
	8 29 50	33	
	10 41 55	61	
	17 42 69		
	20 43 70		
	21 44 75		
MF	47	7 39 67	4
	71	23 51 68	6
	77	27 56 74	
	78	35 60	
	79	36 65	
M	9	14 34 58	
	49	19 52 64	
	80	28 53 66	
		30 57 72	
MS	12 38	15	
	26 46	22	
	37 82	63	
B		54	11 25 76
		59	13 32 81
		62	16 40
		73	18 45

NUMERICAL DISTRIBUTION

Group		1	2	3	
Pattern	A	18	3	-	= 21
	MF	5	13	2	= 20
	M	3	12	-	= 15
	MS	6	3	-	= 9
	B	-	4	10	= 14
		32	35	12	= 79 (Total)

TABLE 8

RELATION OF ROUTINE E.E.G. RATINGS TO GROUPS 1, 2 AND 3

Group 1: Alpha activity is dominant feature.
2: Dysrhythmic quality is dominant feature.
3: Low voltage is dominant feature.

Distribution by subject's code #

	Group 1	2	3
Rating 1	20 44	33 56	4
	24 55	35 59	40
	41 69	54 65	
	42 75		
2	17 47 78	53	11
	29 48 79	60	18
	37 70 80	61	45
	38 71	67	76
	43 77	72	
3	9	14 51 75	13
	12	27 53	25
	46	28 58	32
	50	34 64	81
4	8	7 30 62	6
	21	15 31 63	16
	26	19 36 66	
	49	22 39 68	
	82	23 57 74	
5	5		
	10		

NUMERICAL DISTRIBUTION

Group	1	2	3	
Rating 1	8	6	2	= 16
2	13	5	4	= 22
3	4	9	4	= 17
4	5	15	2	= 22
5	2	-	-	= 2
	32	35	12	= 79(Total)

TABLE 9

E.E.G. RATING, TYPE OF E.E.G. PATTERN, FREQUENCY AND GROUP DIVISION

Distribution by subject's code #

NORMAL				BORDERLINE				ABNORMAL			
AV#	TYPE	α	GR.#	AV#	TYPE	α	GR.#	AV#	TYPE	α	GR.#
4	MF	10.	3	9	M	10.5	1	5	A	9.5	1
11	B	11.	3	12	MS	9.5	1	6	MF	12.	3
17	A	9.	1	13	B	11.	3	7	MF	12.	2
18	B	10.	3	14	M	10.	2	8	A	10.	1
20	A	9.5	1	25	B	10.	3	10	A	10.5	1
24	A	10.	1	27	MF	13.	2	15	MS	8.5	2
29	A	10.	1	28	M	11.5	2	16	B	11.	3
30	A	9.5	2	32	B	11.	3	19	M	10.	2
36	MF	11.	2	34	M	11.	2	21	A	8.5	1
37	MS	9.5	1	46	MS	9.	1	22	MS	10.	2
38	MS	10.	1	50	A	10.	1	25	MF	11.	2
40	B	11.	3	51	MF	10.	2	26	MS	9.	1
42	A	9.5	1	53	M	10.	2	30	M	10.	2
43	A	9.5	1	58	M	9.	2	31	A	10.	2
44	A	10.	1	64	M	10.	2	33	MF	12.	2
45	A	10.	1	75	B	10.5	2	39	MF	11.	2
45	B	13.	3	81	B	11.	3	49	M	9.5	1
47	MF	12.	1					57	M	10.	2
48	A	10.	1					63	M	10.	2
52	A	10.	2					67	MS	10.	2
54	B	11.	2					72	M	11.	2
55	A	10.	1					83	MF	11.	2
56	MF	11.	2					74	MF	11.	2
59	A	11.	2					82	MS	9.5	1
60	MF	11.5	2								
61	A	10.	2								
65	MF	10.	2								
67	MS	11.	2								
69	A	10.	1								
70	A	10.	1								
71	MF	10.	1								
72	M	10.	2								
75	A	10.	1								
76	B	11.	3								
77	MF	11.	1								
78	MF	10.5	1								
79	M	10.5	2								
80	M	9.	1								

Total: 30 subjects | Total: 17 subjects | Total: 24 subjects

Patterns	A	MF	M	MS	B	
Normal	15	11	3	2	7	= 38
Borderline	1	2	7	2	5	= 17
Abnormal	5	7	5	5	2	= 24
	21	20	15	9	14	= 79 (Total)

Freq. of	8.5-9	9	9.5	10	10.5	11	11.5	12	13	
Normal	0	1	5	18	2	9	1	1	1	= 38
Borderline	0	2	1	6	2	4	1	0	1	= 17
Abnormal	2	1	3	88	1	6	0	3	0	= 24
	2	4	9	32	5	19	2	4	2	= 79 (Total)

Groups	1	2	3	
Normal	21	11	6	= 38
Borderline	4	9	4	= 17
Abnormal	7	15	2	= 24
	32	35	12	= 79 (Total)

SUPPLEMENT II

Editor's Note: Preliminary Analysis of the Validity of the E.E.G. as a Predictor.

SUPPLEMENT II: Editor's Note

PRELIMINARY ANALYSIS OF THE VALIDITY OF THE E.E.G. AS A PREDICTOR

Subsequent data have made possible a preliminary analysis of the degree of flight success of the C.A.A. subjects used in the study by P.A. Davis (Supplement I.)

A committee of three instructors at the airport rated the subjects used in this study as "average" or "very good" pilots in flight aptitude or as "potential washouts" or "very poor pilots". These data on flight performance were supplied by Dr. Ross A. McFarland, a Project Director of the National Research Council Committee on Selection and Training of Aircraft Pilots and were used by Dr. H. Davis in the preparation of the following tables:

TABLE I

	E.E.G. Rating					
	1	2	3	4	5	Total
"Average" and "very good" pilots	13	11	11	10	2	47
"Washout" and "very poor" pilots	3	8	6	11	0	28
Total	16	19	17	21	2	75
Per cent success	81	58	65	48	100	63

TABLE II

	E.E.G. Pattern					
	A	M.F.	F	M	MS	Total
"Average" and "very good" pilots	17	11	9	7	4	48
"Washout" and "very poor" pilots	4	6	6	7	5	28
Total	21	17	15	14	9	76
Per cent success	81	65	60	50	44	63

In analyzing these tables, Dr. Hallowell Davis points out that "the success of all those who are either type A or rating 1 (or both) is 82%, i.e., 23 out of 28. At the other end of the scale, grouping all who are either rating 4 and 5 or M and MS (or both), the percentage successful is 64 (30 out of 47), which is almost exactly the ratio of the group as a whole; but of those who are both rating 4 or 5 and types M or MS the percentage successful is only 40 per cent (4 out of 10)."

In presenting these data it should be pointed out that the number of cases in the individual cells is too small to permit calculations which might indicate the significance of observed differences. Moreover, validation on successive samples is required as a basic step in validating the predictive efficiency of E.E.G.'s. Nevertheless, the findings are reported as demonstrating essential interest in investigating the validity of E.E.G.'s. Further studies on predictive efficiency of this technique will be found in subsequent reports covering investigations conducted at the Naval Air Station at Pensacola, Florida.