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

November 1, 1944

Dr. Dean R. Brimhall
Director of Research
Civil Aeronautics Administration
Washington 25, D. C.

Dear Dr. Brimhall:

Attached is a report entitled **The Pensacola Study of Naval Aviators, Final Summary Report**, by Ross A. McFarland and Raymond Franzen. 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.

In the fall of 1939, the Committee on Selection and Training of Aircraft Pilots undertook a major study in the selection and training of aircraft pilots in cooperation with the United States Navy, using funds provided by the Civil Aeronautics Administration. As a result, when the United States entered World War II, there were already available findings and materials which could be utilized in the formulation of Navy standards for the selection and training of pilots.

While the results of this study had been available to the Navy for some time, the findings have been brought together for the first time in the form of the formal report in the attached publication.

As has been indicated in the section on **Acknowledgments**, page v, many individuals in the Navy contributed to the development and completion of this important research project. Acknowledgment is particularly due to the officers who were in command at Pensacola Naval Air Station at the time of this investigation for their cooperation in making this study possible, especially Rear Admiral (then Captain) A. C. Read, Commandant; Captain Frederick Ceres, Senior Medical Officer; and Commander William D. Sample, Superintendent of Training.

Special thanks are due the medical staff at the dispensary and the liaison officers, Captain Victor G. Armstrong and Commander Wilbur E. Kellum, for expediting the research program; also, to Captain John R. Poppen, M.C., Bureau of Aeronautics, for his assistance in sponsoring the project in the Navy Department.

Acknowledgment is also due Dr. John G. Jenkins (now Commander USNR-HV(S)), Chairman of the Committee on Selection and Training of Aircraft Pilots at the time this study was undertaken, for the part he played in designing and expediting the investigation.

As indicated in the Foreword to the attached report, in addition to providing positive findings, the Pensacola Study played a valuable role in the research program of the Committee on Selection and Training of Aircraft Pilots in underlining the need for improved criteria; in pointing the way towards further investigations of physical and physiological measures; in revealing the possibility of biographical items as predictors; and in directing attention toward other areas requiring investigation which have been the subject of more recent studies by the Committee on Selection and Training of Aircraft Pilots.

Cordially yours,

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

MSV:rm

ACKNOWLEDGMENTS

Grateful acknowledgment is made to the officers who were in command at Pensacola Naval Air Station at the time of this investigation for their cooperation in making this study possible, especially to Rear Admiral (then Captain) A. C. Read, Commandant; Captain Frederick Ceres, Senior Medical Officer; and Commander William D. Sample, Superintendent of Training.

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Acknowledgment is also due Dr. John G. Jenkins (now Commander USNR-HV(S)), Chairman of the Committee on Selection and Training of Aircraft Pilots at the time this study was undertaken, for the part he played in designing and expediting the investigation.

The members of the Research Staff who played an active part in the experimental studies which make up this paper were the following U. S. Naval Reserve Officers on active duty at Pensacola at the time this work was conducted: Lt. Comdr. Ross A. McFarland, Ph. D. (Physiological-Psychology), Harvard University; Lt. Comdr. Ashton Graybiel, M. D. (Cardiology), Harvard University; Lt. Comdr. Alexander Forbes, M. D. (Physiology), Harvard University; Lt. R. A. Phillips, M. D. (Physiology), Cornell University; Lt. Donald G. Gates, M. D. (Clinical Medicine), Harvard University; Lt. Carl Pfaffmann, Ph. D. (Physiological-Psychology), Brown University; Lt. Ralph Channell, B. A. (Psychology), Harvard University; Lt. (jg) Stanley Bennett, M. D. (Anatomy and Pharmacology), Harvard University; Lt. (jg) Fred Webster, B. A. (Physiology), Harvard University.

Research workers of civilian status at Pensacola at the time this work was undertaken, and who contributed to this research, were: Hallowell Davis, M. D. (Physiology), Harvard University; Hudson Hoagland, Ph. D. (Physiology), Clark University; Robert Peckham, Ph. D. (Physiological Optics), Dartmouth Eye Institute; Craig Wilson, M. A. (Optometry), Dartmouth Eye Institute; Allen Davis and Mahlon Hoagland, Technical Assistants.

The following enlisted men (Hospital Corpsmen and Seamen) participated in the study as laboratory assistants: Messrs. Aller, Babst, Backus, Batts, Baumgarten, Kirkland, Hansen, Lawhead, Myers, Parrish, Snowden, Riles, Van Meter, and Schwartz.

The statistical staff whose aid was invaluable in this investigation consisted of: Raymond Franzen, Ph. D., Statistical Consultant of the C.A.A.; Philip S. Lawrence, Sc. D. (Biometrics), Harvard University; Helen M. Mitchell, M. A., Harvard University; Donald Straus, M. B. A., Harvard University.

The final reports on this project were prepared with the close cooperation of the Editorial Staff of the Committee on Selection and Training of Aircraft Pilots.

EDITORIAL FOREWORD

The Pensacola Study, summarized in this report,[1] symbolizes, to some extent, the renascence of the military application of aviation psychology during World War II. Research in this area had come virtually to a standstill in the United States at the close of the last war, except for scattered studies conducted in the main by flight surgeons located at Randolph Field and elsewhere.[2] Progress, as is suggested in a recent reference to post-war psychological research on selection in the United States Navy, was "slow, laborious, and uncertain."[3]

By 1941, however, when the United States entered the war, a well organized program of research was under way which, through the Pensacola Study and other investigations, had produced test material and criterion data utilized directly in the formulation of Navy standards for the selection of pilots and indirectly in the organization of other military selection procedures.

This development is largely traceable to the support given to psychological research in aviation since 1939 by the Civil Aeronautics Authority (later the Civil Aeronautics Administration). Through the efforts of its Director of Research, Dean R. Brimhall, a sum was set aside for psychological research in the selection and training of civilian aircraft pilots. This fund, increased as the Civilian Pilot Training Program expanded, was allocated to the National Research Council for use by the Committee on Selection and Training of Civilian Aircraft Pilots in planning and supervising research on the human aspects of aviation.

The original program of research was centered on personnel problems in civilian flying. However, a year and a half before Pearl Harbor, in the summer of 1940, the functions of this National Research Council Committee on Selection and Training of Aircraft Pilots were expanded, with the consent of the Civil Aeronautics Administration, to include military as well as civilian aviation.[4] This concern for the military aspects of civilian aviation

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[1]Omitted from the summary is the investigation of biographical items as predictors. See: Johnson, H. M. On the actual and potential value of biographical information as a means of predicting success in aeronautical training. Washington, D. C.: C.A.A. Airman Development Division, Report No. 32, August 1944.

[2]Prepared by the National Research Council Committee on Selection and Training of Aircraft Pilots. An historical introduction to Aviation Psychology. Washington, D. C.: C.A.A. Division of Research, Report No. 4, October 1942, pp. 57-58.

[3]Psychological tests made part of initial aviation physical examination. Aviation Supplement, BuMed News Letter, Navy Department. Vol. 2, No. 13, June 23, 1944, p. 5.

[4]The name of the Committee was accordingly changed to Committee on Selection and Training of Aircraft Pilots.

led to the initiation of the Pensacola Study, conducted under the auspices of the Committee in direct cooperation with the Bureau of Aeronautics of the United States Navy.

The history and major findings of this study[5] are summarized in the present report. The purpose of this summary report is merely to present a description of the experimental procedure, the psychological and physiological tests and measures used, and the populations employed in the investigation. Only such general statistical data as are necessary for an evaluation of these instruments as predictors of flight success are discussed. The report serves as a background for other reports on the Pensacola Study which present the detailed statistical treatment applied to various individual aspects of this study. Several of these reports have already been issued[6] and others are in the process of preparation.

The reader of this report will quickly become aware of the fact that the investigation was exploratory in character. The study was designed to provide for the application of a wide variety of physiological and psychological measures with a view of quickly arriving at those deemed promising for future research. Under the circumstances, it is not surprising that many of the results with respect to individual items are inconclusive in character. This is particularly true of the physiological tests, where the unreliability of the techniques employed made impossible a final and definitive investigation of their validity. Many of the other results are negative, even though the original measures were reliable. Such negative findings have, however, played a most useful role in preventing the use without validation of tests and measures which, in spite of face validity, prove not to predict success in learning to fly. Together with such inconclusive and negative findings are many positive findings on the value of predictors which have pointed the way to major developments in the selection and classification of pilots.

There were many defects and difficulties in the Pensacola Study. For example, the investigation was limited by the fact that all cadets employed in the

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[5]Except for the investigation of biographical items as predictors.

[6]Forbes, Alexander and Davis, Hallowell. Electroencephalography of Naval Aviators. Washington, D. C.: C.A.A. Division of Research, Report No. 13, April 1943.

Franzen, Raymond and Blaine, Louisa. Evaluation of respiratory measures for use in pilot selection. Washington, D. C.: C.A.A. Division of Research, Report No. 25, January 1944.

Johnson, H. M. Op. cit.

McFarland, R. A. and Channell, R. C. A revised serial reaction time apparatus for use in appraising flying aptitude. Washington, D. C.: C.A.A. Airman Development Division, Report No. 34, September 1944.

McFarland, R. A. and Channell, R. C. A revised two-hand coordination test. Washington, D. C.: C.A.A. Airman Development Division, Report No. 36, October 1944.

study had successfully completed 10 hours of flight training. The findings of this study therefore do not furnish conclusive evidence as to the efficiency of the tests when administered before flight training is started. Furthermore, medical examinations administered at the time of application for flight training (and repeat examinations during the first ten hours of training) resulted in a sample that was highly selected in terms of medical standards with, possibly, a resultant decrease in the apparent effectiveness of the physiological measures. Finally, there were certain changes in the test procedures and in the educational background of the cadets between the earlier and later phases of the study, so that the two phases are not strictly comparable.

In spite of such defects the Pensacola Study, together with parallel studies, had immediate and useful outcomes. As early as February, 1941, it was possible for a representative of the U. S. Navy to write:

> "The results of the researches conducted thus far by the group at Pensacola and by other members of the Committee are so promising that we have reason to expect a much better selection of our students within a very short time. This will constitute a very constructive contribution to the national defense. It is the judgment of several of us that achievements thus far exceed those of the past 25 years in this field."[7]

A few months after this was written, at the annual meeting of the Division of Anthropology and Psychology, National Research Council, held in April, 1941, Dr. J. G. Jenkins, then Director of Research of the Committee on Selection and Training of Aircraft Pilots, was able to furnish specific evidence on the immediate usefulness to the military services of the findings of the Pensacola Study and allied investigations.

> "Last summer a staff of 15 men from our program went to the Naval Air Station at Pensacola for a period of intensive research on a battery of selective tests. At least a skeleton force has been maintained there ever since. In addition to this, representatives of the Committee have worked on a half-dozen special projects for the Bureau of Aeronautics. Two tests developed by the Committee have already been adopted for routine use in all primary Naval Air Bases. Four or five others will be adopted as soon as a field verification at primary bases can test preliminary results obtained at Pensacola. One member of the Committee has engaged in an extended program of analyzing and weighting biographical and test data available at Pensacola and the results of this analysis will soon be ready for military use."[8]

In addition to such positive findings, perhaps limited in extent, the Pensacola Study also played a valuable role, in the research program of the Committee on Selection and Training of Aircraft Pilots, in underlining the need for improved criteria; in pointing the way toward the further investigation of physical and physiological measures; in revealing the possibility of biographi-

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[7]Quoted from report of J. G. Jenkins, Director of Research, Committee on Selection and Training of Aircraft Pilots, Division of Anthropology and Psychology, National Research Council, Annual Meeting of the Division, 1941, Appendix M, p. 4.

[8]Ibid.

cal items as predictors; and in directing attention toward other areas requiring detailed investigation.

Apart from experimental findings, the Pensacola Study, as is pointed out in the report by Dr. J. G. Jenkins to which reference has been made, had a most valuable outcome in the establishment, on a basis of mutual respect, of a day-to-day liaison with the personnel of the Bureau of Aeronautics and of the Bureau of Medicine and Surgery of the U. S. Navy. From this has emerged a pattern of collaborative effort between the military and the civilian personnel of the Committee on Selection and Training of Aircraft Pilots that has made possible the most effective use in both military and civilian aviation of research conducted under the auspices of the Committee on Selection and Training of Aircraft Pilots.

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SUMMARY

This report provides an overall summary of an exploratory investigation of the value of psychological and physiological tests in the prediction of success in naval aviation cadet training. It is based upon data obtained from July, 1940 to May, 1941 when naval aviation cadets in classes 147 to 165 at the Naval Air Station, Pensacola, Florida, were given a large battery of psychological and physiological tests and the test results compared with later success in the training program, in terms of passing or failing the flight course and appearance before the Commandant's Board.

The testing program included the following types of measures: (1) mental ability, mechanical aptitude, and athletic achievement; (2) psychomotor abilities; (3) visual perception; (4) metabolism and respiration; (5) physical fitness; (6) electrocardiograms, response to startle, circulatory reflexes; (7) electroencephalograms; and (8) body build.

The study was divided into two parts and the results treated separately. Part I subjects were formed of classes 147-151 and Part II subjects of classes 152-165. This division was made since (1) the two groups differed in educational background, and (2) the experimental conditions were not exactly comparable for the two groups.

A more detailed statistical analysis of the tests will be presented in subsequent reports. This summary report presents over-all findings with respect to the battery as a whole and to individual tests. In general, the following tentative conclusions may be drawn from the results:

1. The psychological tests as a group differentiated the successful pilots from the poor pilots (washouts and board appearances) with a greater degree of efficiency than did the physiological tests. In both Part I and Part II the tests of greatest significance were (a) Otis Test of Mental Ability, (b) Eye-Hand Coordination Test, (c) Eye-Hand Coordination Test, (d) Washburn Serial Action Test.

2. The physiological tests, in general, were not successful in differentiating the good from the poor pilots. Several, however, approached acceptable levels of predictive significance sufficiently close to warrant further investigation, especially if their reliability were increased by use of repeated measures.

The results of this investigation should be interpreted in the light of the fact that it was designed as an exploratory study. In addition, the subjects were pre-selected, in that their initial selection as aviation cadets included a rather severe medical examination and in that, prior to entering Pensacola, they had survived 10 hours of preliminary flight training. The population, therefore, does not include the majority of washouts since they were eliminated during this preliminary flight training.

THE PENSACOLA STUDY OF NAVAL AVIATORS
FINAL SUMMARY REPORT

by

Ross A. McFarland

and

Raymond Franzen

A report on research conducted at the Naval Air Station, Pensacola, Florida, in cooperation with the Bureau of Aeronautics of the U. S. Navy and the Division of Research, Graduate School of Business Administration, Harvard University, 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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Committee on Selection and Training of Aircraft Pilots

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THE PENSACOLA STUDY OF NAVAL AVIATORS
FINAL SUMMARY REPORT

INTRODUCTION

When world affairs pointed toward an approaching rapid expansion in the pilot training programs of the military services, the National Research Council Committee on Selection and Training of Aircraft Pilots directed its attention toward research on the selection of military as well as civilian pilots. The Pensacola Study, described in this report, represents an effort in this direction undertaken in close cooperation with the U. S. Navy.

Although there had been attempts during and after World War I to develop selection tests for aircraft piloting, there was little in the way of well-validated test techniques available in 1939 when the need for pre-selecting pilot trainees so as to reduce attrition rate became urgent. Isolated studies had been made with single tests (or small batteries) measuring various sensory, intellectual, psychomotor, and emotional characteristics, but an extensive survey study was needed in order to explore the possible predictive value of tests representative of those developed during the expansion of industrial and educational testing in the 1920's and 1930's.[1]

The Pensacola Study, conducted at the Naval Air Station, Pensacola, Florida, was undertaken with this end in view. In this study a series of psychological and physiological tests was administered to a large number of naval aviation cadets in an attempt to identify tests which would be of value in predicting success in the pilot training program.

It was recognized, when the study started, that subjects undergoing flight training at the Naval Air Station were pre-selected, in that they had been required to pass a rather severe medical examination and had, in addition, survived a 10-hour flight training course, including solo flight, at elimination bases before being sent to Pensacola. However, the practical consideration of the availability of large groups of subjects who could be submitted to tests under controlled conditions warranted the use of the cadets as subjects.

Laboratory equipment was either purchased or rented for the duration of the study, specialized personnel enlisted from several universities, and a number of reserve officers called to active duty to form the research staff. A building was assigned at the Naval Air Station for use as the experimental laboratory. The laboratory was fully equipped during June, 1940. In addition, a number of laboratory assistants and hospital corpsmen were assigned to the project from the dispensary at the station. The testing program began with Class 147 during the third week of July, 1940 and testing continued

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[1] An historical introduction to aviation psychology. Washington, D. C.: C.A.A. Division of Research, Report No. 4, October, 1942.

for approximately one year, until May, 1941.

SUBJECTS

The experimental battery of tests was administered to all of the incoming cadets and officers in each class at Pensacola during the period from July 16 to September 20, 1940 (classes 147 through 151). Twelve cadets and officers were studied each day during their ground school period and before their flight training. The data collected during this period have been treated separately and are designated throughout this report as Part I.

Because of the small number of washouts in this group it was decided to extend the study. From October 1 to December 15, 1940, a representative sampling comprising about one fifth of each incoming class was tested (classes 152 through 159). During this period only five subjects could be studied each day because of the reduction in the size of the research staff. From January 1 to May 15, 1941, only those cadets who appeared before the Commandant's Advisory Board took the tests (classes 160 through 165). The data obtained after September, 1940 are designated as Part II.

These two parts of the study have been treated separately because the two populations were not comparable in all respects. It has also been shown that they differ statistically. This difference may be partially explained by the following considerations: The subjects in Part I, for instance, included 88 officers from the U. S. Naval Academy who had recently been commissioned as Ensigns. The cadets in Part I were college graduates, however, and since both cadets and officers had the same amount of flight training before their entrance at Pensacola, they were treated as one group. Part II subjects included a considerable number of men assigned to Pensacola from the Fleet with only high school diplomas, and many others in Part II had only two years of college. Because the subjects in Part II had less academic training than those in Part I, it was felt that the differences in education might be an important variable in that they had had less experience in taking tests and examinations of this nature. Finally, there were certain differences in the experimental procedure in the two parts of the study due to a reduction in the Research Staff and to other factors discussed more fully below under experimental procedures.

Besides the differences in the experimental groups the limitation mentioned in the Introduction must be kept in mind throughout the interpretation of the results, namely, that all of the subjects in both parts of the study had had 10 hours of previous dual flight instruction and had soloed before entering Pensacola Naval Air Station for further training. The early washouts are, therefore, not included in the experimental population.

A group of 83 instructors at the Naval Air Station were also given the tests so as to obtain norms for pilots known to be successful. Their average age was 27 years, and they had an average of 1,500 hours of flying. Table 1 shows the total number of aviation cadets, officers, and instructors who took the tests at Pensacola.

abroad, industrial selection research, and preliminary studies made at Harvard University and other universities just previous to the Pensacola Study. A number of measures were included, such as electrocardiograms and metabolism, not primarily as tests related to flight success, but with the view of studying specific abnormalities which might be considered as disqualifying in terms of "a priori" medical standards.

A brief description of each test selected for use in the experimental battery is given below.

The Psychological Tests

I. Interview - Personal and Medical History

An interview and questionnaire relating to personal and medical history and other items were given to each cadet at the laboratory. The items in the questionnaire related to (1) family history; (2) personal and medical history, with special reference to accidents, illnesses, and nutritional habits; (3) environmental influences; (4) education; and (5) vocational and aeronautical interests. A physician went over the answers and interviewed each cadet relative to the most significant clinical data such as the major illnesses, loss of consciousness from accidents, diet, and vocational interests, especially aviation.[2] A sample of the form with a summary tabulation is shown in Appendix A. This form includes all of the revisions.

II. Paper-and-Pencil Tests Given in a Group

Mental Ability (Otis Higher Examination - Form D).[3] This is a test of general intelligence containing 75 questions. Each student was allowed 20 minutes for the test. A high score on this test indicates superior performance. The author reports a reliability coefficient of .92 for the test.

Mechanical Aptitude (Minnesota Paper Form Board).[4] (Revised series AA.) This test involves the perception of form relations and is supposed to be predictive of mechanical aptitude. A high score indicates superior performance. The authors report a reliability coefficient of .85 for the test.

2Editor's Note. It must be noted that these "significant clinical data" have never been validated in the flight situation and that the physician's interview itself is of questionable reliability.

3Otis, S. A. Manual of directions. New York: World Book Company, 1922.

4Patterson, D. G., Elliott, R. M., Anderson, R., Toops, H. A., Heidbreder, E. Minnesota mechanical ability tests. Minneapolis, Minnesota: The University of Minnesota Press, 1930. p. 310.

Quasha, W. H. and Likert, R. The revised Minnesota paper form board test. J. Educ. Psychol., 1937, 20, 197-204.

TABLE 1

NUMBER OF CADETS, OFFICERS, AND INSTRUCTORS TESTED AT PENSACOLA

Part	Classes	Dates Tested	Total	Washouts	Board Appearances who were retained
	Cadets & Officers:				
I	147-151	July 16 to Sept. 20, '40	390	55*	34
II	152-165	Oct. 1, '40 to May 15, '41	529	125**	96
	Instructors:	July 16 to Sept. 20, '40	83	-	-
		Total	1,002	180	130

*Total number of Washouts includes 16 who left at their own request or for reasons other than aptitude.

**Total number of Washouts includes 23 who left at their own request or for reasons other than aptitude.

DESCRIPTION OF THE TESTS EMPLOYED

No job analysis descriptive of the characteristics required in successful piloting was available as a guide in the selection of an appropriate test battery. Relevant information was obtained by examining the "flight jackets" of a group of Pensacola cadets who had previously failed and been "washed out." These flight jackets included comments from flight instructors as to the cause of the cadet's failure. Among the more common causes of failure occurring in these comments were:

1. "He was emotionally unstable,"
2. "He was tense and unable to relax,"
3. "He had poor coordination and could not handle the controls accurately and smoothly,"
4. "He was unable to perceive distances accurately,"
5. "He had poor judgment,"
6. "He was unable to think in difficult situations,"
7. "He lacked poise, military bearing, or the ability to command."

Such statements suggested that the causes of failure were numerous and that no single test could be expected to eliminate all of those who might fail. It was hoped, however, that the administration of an extensive battery of tests, varied in nature, might reveal those with sufficient predictive efficiency to warrant further, more intensive validation. A survey was thus made of what seemed to be promising tests on the basis of World War I experience, pilot selection studies since that time both here and

Athletic Achievement (Thorndike-Kelley). This test contains 42 questions relating to proficiency in various athletic events and to manual dexterity and coordination. A higher score indicates superior performance. A sample form is shown in Appendix B.

III. Psychomotor or Coordination Tests given Individually

Eye-Hand Coordination Test.[5] This instrument is designed to measure motor dexterity and ability to coordinate the eyes and hands. A pointer, controlled by the subject, is to be kept opposite a second pointer controlled by an irregular cam (see Fig. 1). The cumulative amount of deviation made by the subject while attempting to follow the moving pointer is recorded automatically. There are four different patterns on the cam which regulate the movements of the pointer. The test is essentially a motor-learning task since improvement is shown in repeated trials. Eight successive trials were given in order to analyse the rapidity and skill with which a subject showed improvement, as well as to give a reliable total score.[6] The score, the mean of 8 trials, measures the amount of displacement. A low score indicates superior performance.

Two-Hand Coordination Test. This test, constructed on the principle of a lathe, involves the rotation of two handles which control the movement of a disc (see Fig. 2). The handles must be turned simultaneously in different directions in order to keep two pointers together. One of these discs is actuated in an irregular manner by a cam. The essential psychological principle involves the competition of simultaneous stimuli; i.e., attending to two different acts or movements at the same time. The final score was based on a mean of four trials. A low score indicates superior performance.[7]

Mashburn Serial Action Apparatus.[8] The apparatus roughly simulates the stick and rudder movements involved in flying (see Figs. 3 and 4). The subject reacts to a continuous series of red lights on the instrument panel.

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[5]Farmer, E., Chambers, E. G., and Kirk, F. J. Tests for accident proneness. Medical Research Council. Report No. 68. London: His Maj. Stat. Off., 1933.

[6]In a study subsequent to the Pensacola project a test-retest correlation of .71 was obtained on a group of 89 Civilian Pilot Training students in the Boston area, using a revised form of the test. See: Wantman, M. J. Report on research activities. November 14, 1942. (Copy in Committee files.)

[7]In subsequent studies using a revised form of the Two-Hand Coordination Test, inter-trial correlations ranging from .36 to .74, and test-retest correlations of .75 and .50 on two samples, were obtained. See: McFarland, R.A. and Channell, R.C. A revised two-hand coordination test. C.A.A. Airman Development Division, Report No. 36, October 1944.

[8]Mashburn, N. C. Mashburn automatic serial action apparatus for detecting flying aptitude. J. Aviation Med., 1934, 5, 155-160. Ibid, 1934, 5, 145-154.

The responses are made by movements of the set of controls operated by the hands and feet. As soon as the subject has made a correct response to a set of signals, another pattern of signals automatically appears. There are 40 settings to which a subject responds. After a brief practice period of 6 settings, the subject is told to begin. The score is given in terms of the number of minutes and seconds that it takes to make the 40 settings.[9] A low score indicates superior performance.

Dotting Test (McDougall).[10] The purpose of this test is to measure quickness of one type of reaction time and the facility for quickly and accurately coordinating eye-hand movements. The task involves striking small holes on a revolving disc with a stylus (see Fig. 5). The speed of rotation increases as the row of dots reaches the external part of the revolving phonograph plate. The score is based on a mean of three trials, a high score indicating superior performance.

Continuous Reaction Test (Cattell).[11] The purpose of this test is to measure the speed and accuracy with which a person can react to directions printed on a moving strip of paper. The subject is instructed to mark (with a pencil) all the vertical lines on the strip as it moves by the aperture on the apparatus (see Fig. 6). He is instructed not to mark certain other lines which appear at various intervals. The subject must think and act simultaneously and with great rapidity. The test is designed to measure close attention, quick thinking, and accurate manual dexterity. It is scored in terms of the total number of correct markings on the strip of paper. It is given twice, once while the strip of paper is moving slowly and, again, while it is moving rapidly, the second time with different directions. A high score on both the slow strip and the fast strip indicates superior performance.

Ataxiameter (Miles).[12] This apparatus measures the amount of vertical sway in the axis of the body while standing at attention with the eyes open or closed. The apparatus, as shown in Fig. 7, is made up of a series of weights and pulleys activated by cords attached to the subject's head. A movement in any direction is recorded by the counters at each corner of the metal framework. The subject is asked to stand as steadily as possible with heels together and feet turned outward at a 45-degree angle. The test was given first with the eyes open as a practice period. The data were analyzed

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9Later studies of the reliability of a revised form of the Ashburn apparatus yielded test-retest correlations of .53 and .74 on two samples of cases. See: Wantman, M. J. Op. cit.

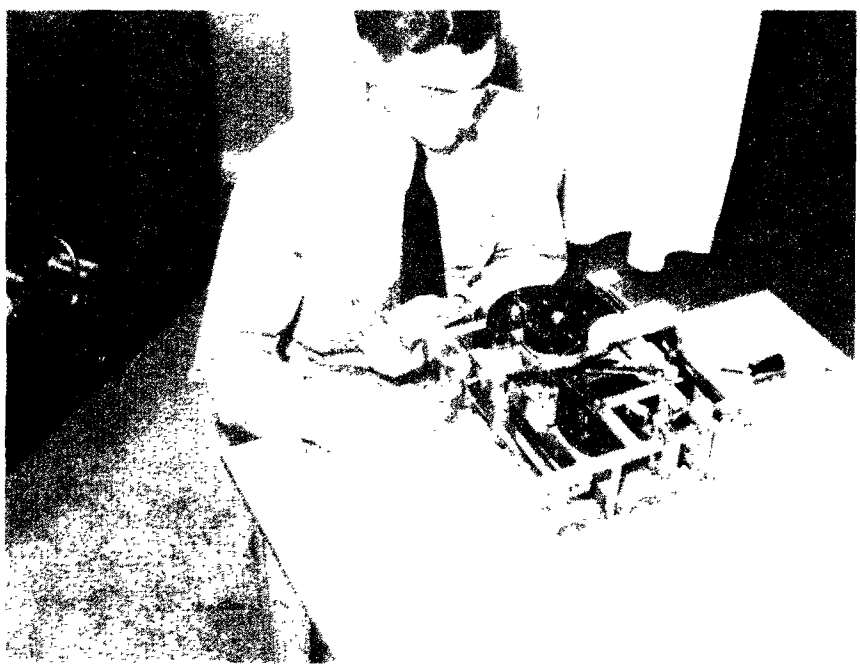
10McDougall, W. and Smith, M. Effects of alcohol and some other drugs during normal and fatigued conditions. Med. Research Council, Report No. 56 London: His Maj. Stat. Off., 1920.

11Cattell, R. B. An objective test of character-temperament. J. Gen. Psych. 1941, 25, 59-73.

12Miles, W. R. Static equilibrium as a useful test of motor efficiency. Jour. Ind. Hyg., 1922, 3, 316.

EYE-HAND COORDINATION TEST

Figure 1



TWO-HAND COORDINATION TEST

Figure 2

MASHBURN SERIAL ACTION APPARATUS
(Front View)

Figure 3

MASHBURN SERIAL ACTION APPARATUS
(Back View)

Figure 4

DOTTING TEST (McDOUGALL)

Figure 5

CONTINUOUS REACTION TEST (CATTELL)

Figure 6

on the basis of two readings of one minute each with the eyes closed. The amount of movement in each direction is automatically recorded. The test score is the mean of the 2 one-minute readings. A low score indicates superior performance.

IV. Visual and Perceptual Tests

Aniseikonia. The perception of space (in landing a plane or in formation flying) appeared to require consideration. Three tests were used which were developed by the Dartmouth Eye Institute in its work on aniseikonia. Aniseikonia is defined as a defect of the binocular visual processes in which differences exist in the size or shape of the ocular images from the two eyes. Such differences have been shown to result in false space localization when the individual is placed in an environment where strong perspective monocular clues do not exist[13].

1. Eikonometer. This apparatus determines the difference in the size and shape of the ocular images by projection. The score represents the sum of the size difference in either the horizontal or vertical meridian and the size limits in the vertical and horizontal meridian. The measures are coded in numbers from 1 to 3.

2. Leaf Room. The subject is asked to judge the shape of a rectangular room, the surfaces of which are covered with oak leaves which provide adequate contours and yet do not introduce strong perspective features. Failure to see the room in its proper perspective is considered as evidence of distortion in space perception. The final score represents the sum of two scores: the "response score" and the "plane lens test score." The codes for the response score range from 0 to 4 and for the plane lens score from 0 to 2.

3. Frontal Plane Apparatus. In this test the subject sets a series of rods for an apparent frontal plane under different test conditions. The test is based on the same principle as the Howard-Dolman apparatus, but several refinements have been introduced. The score represents the sum of the following: curvature of curve determined by rods, response to distortion lenses, scatter of data, response to cycle incongruities, response to various eye lenses, and displacement of data from normal.

Photographs of Eye Movements (Ophthalmograph).[14] The purpose of the test is to record the number of fixations while reading and to measure the ocular motor anomalies while fixating on a target. The principle of the apparatus is as follows: a beam of light is focused on the cornea, and the reflection of the light is recorded on the film of a moving picture camera. The subject is asked first to fixate on a dot, then to focus alternately on one dot and then on another at a rate determined by a metronome. Finally, he is asked

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[13] Ames, A. Aniseikonia, a factor in functioning of vision. Am. J. Ophthal., 1935, 18, 1014.

[14] Taylor, E. A. Controlled Reading. Chicago, Illinois: University of Chicago Press, 1937.

to read printed lines from the page of a book. The score is based on the number of fixations per line. A low score indicates superior performance.

Dark Adaptation (Wald). This test was included in the battery, not as a selection test, but for evaluating the nutritional state of the pilots in relation to ability to see at night. Night vision tests were given with the Hecht and Wald Adaptometers. The Hecht apparatus[15] exposes the eyes to a bright light for three minutes. The return of the ability to see in the dark is measured accurately in terms of the sensory threshold. The light is controlled by a system of filters and an optical wedge. There are fairly wide individual variations in this test, which have been ascribed, in part, to the nutritional state of the body. Wald[16] devised a simple portable apparatus for field use which involves the determination of a number of points on the dark adaptation curve after the subject has remained in the dark for 30 minutes. These determinations take only 5 minutes, so that approximately 18 to 20 subjects can be tested in an hour if properly dark adapted. After the study was in progress, it was found to be impracticable to use the Hecht apparatus which takes 30 minutes per subject; hence, only data with the Wald apparatus are shown in this study. The score is based on the mean of 4 readings and is expressed in micromillilamberts; a low score indicates superior performance.

Tilt Chair - Perception of Change in Position. The object of this test is to measure the perception of change in position while the subject is seated blindfolded in a chair (see Fig. 8). The procedure is to have the subject indicate the moment at which he is aware of whether the chair is being tilted to the right or to the left, forward or backward. The tilting movements are controlled by a set of gears located under the chair. The rate at which the subject is tilted is determined by a metronome set at approximately 7.4 beats per second. The score is based on the mean of 8 trials. A low score indicates superior performance.

The Physiological Tests

I. Metabolism and Respiration Tests[17]

Basal Metabolic Rate. Basal metabolism determinations were made on each pilot, not only to evaluate abnormalities in oxygen consumption, but also to study other data from the spirogram, such as tidal air volume, vital capacity, and characteristics of the breathing pattern. Four nine-liter Benedict closed-circuit spirometers, constructed by the Sanborn Instrument Company, were used. Each pilot was tested in the morning under basal conditions (see Fig. 9). The score on the Basal Metabolism test was based on 2 runs of 8 minutes duration each, and was expressed in plus and minus values, the normal range being plus 15 to minus 15. The breathing records allow for the calculation of the oxygen consumption per minute, and also yield a graphic tracing of the respiration (spirogram) (see Figs. 10A and B). In addition, observations were made of the subject's reaction to a resistance placed in the breathing circuit which forced him to breathe through a small opening (pin head in size).

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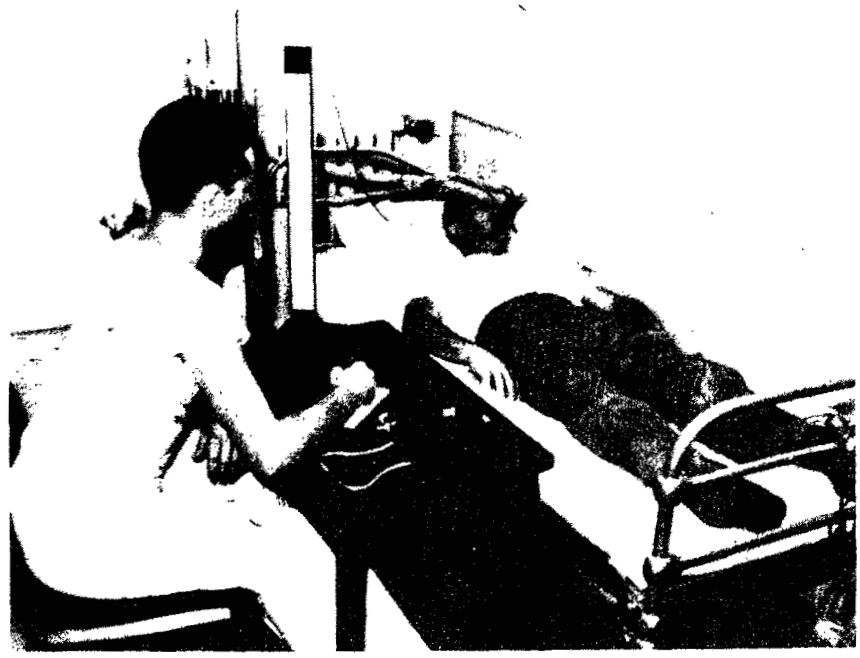
[15]Hecht, S. and Shlaer, S. An adaptometer for measuring human dark adaptation. J. Opt. Soc. Am., 1938, 28, 269-275.

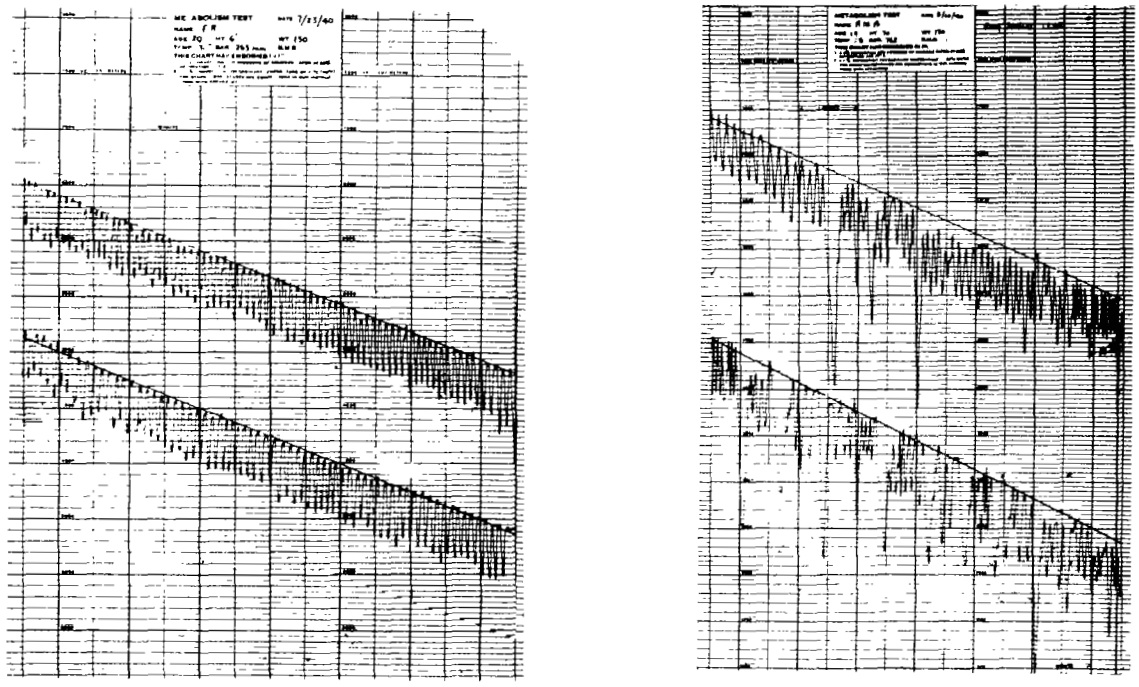
[16]Wald, G. Portable visual adaptometer. J. Opt. Soc. Am., 1941, 31, 235.

[17]A detailed description of these respiratory tests and measures may be found in Franzen, R. and Blaine, L. Evaluation of respiratory measures for use in pilot selection. Washington, D. C.: C.A.A. Division of Research, Report No. 25, January 1944.



AVIATION CADET TAKING THE BASAL METABOLISM TEST

Figure 9



SPIROGRAMS ILLUSTRATING A REGULAR (A)
AND IRREGULAR (B) BREATHING PATTERN

Figures 10A and 10B

ATAXIAMETER (MILES)

Figure 7

TILT CHAIR - PERCEPTION OF CHANGE IN POSITION (STRATTON AND HERMAN)

Figure 8

Tidal Air Volume. Previous studies of tidal air have suggested that large volumes were often found in pilots known to be successful.[18] The tidal air volume is the amount of air breathed in and out of the lungs with every quiet respiration. The average amount for adult males is about 400 to 500 c. cm. It varies with the size of the individual; hence, all values are given in terms of tidal air/body surface. The score, expressed in cubic centimeters, is based on 2 runs of 8 minutes duration each while the subject is in a recumbent position. A high score is considered favorable. An estimated correction for body surface to adjust for variations in body size was made by use of the Height-Weight Graph.[19]

Vital Capacity. The vital capacity is the number of cubic centimeters of air one can forcibly expire after a full inspiration. The average value is about 3500 c. cm. and varies with the size of the individual. Athletes give decidedly higher values. The vital capacity was determined in the following manner. After a normal breathing period, the subject was asked to inhale as fully as possible and then to exhale as deeply as possible. Two records were made on the basal metabolism chart with the subject sitting. The readings are in cubic centimeters; a high score is considered favorable.

Breathing Pattern. Studies in physiology and psychosomatic medicine have suggested that the depth and regularity of breathing often tend to reflect the emotional characteristics of a subject. It is possible, for example, that a person under emotional stress might sigh more frequently, as well as breathe more rapidly and irregularly. This test was included so as to evaluate it as a possible objective measure of emotional stability in aviation cadets. The breathing pattern can be studied from the spirogram (see Figs. 10A and B). The irregularities are analyzed from the standpoint of variations in tidal air volume, respiratory rate, and other characteristics.[20, 21]

II. Physical Fitness Tests

Schneider Index of Neurocirculatory Fitness. This test was developed in the last war and has been widely used in civilian and military aviation to evaluate physical fitness, "fatigue," and "flying stress." It weights

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[18]Thompson, J. W. Studies to develop methods of determining emotional stability. Washington, D. C.: C.A.A. Technical Development Division, Note No. 18, 1939.

[19]Based on the formula for body surface area by Drs. D. and E. F. DuBois. Adapted from Fig. 17, p. 119, in Basal metabolism in health and disease by E. F. DuBois. Philadelphia: Lea and Febiger, 1927. Charts supplied by Warren E. Collins, Inc., Boston, Massachusetts.

[20]Finesinger, J. E. Effect of pleasant and unpleasant ideas on respiration in psychoneurotic patients. Arch. Neurol. and Psychiat. 1939, 42, 425-490.

[21]McFarland, R. A., Graybiel, A., Liljencrants, E., and Tuttle, A. D. An analysis of the physiological and psychological characteristics of 200 civil airline pilots. J. Aviation Med. 1939, 10, 1-52.

data from six sets of observations; namely, the pulse rate during recumbency; the pulse rate while standing; the increase in the number of beats in the pulse rate when standing and recumbent postures are compared; the acceleration of the pulse rate after standardized exercise; the time required for the pulse rate to return to normal after exercise; and the change in the systolic arterial blood pressure when the change is made from recumbency to standing.[22] It penalizes the subject who shows a rapid pulse rate and who fails to show an increase in systolic blood pressure on standing. It is supposed to reveal the state of physical fatigue or of physical fitness of the subject. The scores range from +18 to -11. A score below +7 is considered abnormal.

Tilt Table - Cardiovascular Response to Change in Position. The purpose of this test is to analyze each subject's cardiovascular response to change in position.[23] The tilt table (see Fig. 11) is used under standardized conditions to study the positional circulatory reflexes. It is of interest not only in attempting to evaluate physical fitness and "fatigue," but also in analyzing the subject's susceptibility to fainting. It was included in this investigation because of the possible relationship between ease of fainting on the tilt table and "blacking out" in dive bombing. The subject rests for at least 15 minutes on the table in a prone position before being tilted, then with head up, for a 20-minute period at a 65-degree angle. The following measures were taken during the tilt table test:

1. Systolic Blood Pressure, Diastolic Blood Pressure and Pulse Rate. The scores for each of these measures were expressed as the mean of 5 readings taken when the subject was in a reclining position (before being tilted).

2. Pulse Pressure Change. Pulse pressure indicates the difference between systolic and diastolic blood pressures. The change in pulse pressure is the difference between the average pulse pressure before tilting and the smallest pulse pressure after tilting. A minus score indicates that the pulse pressure is greater after tilting than before tilting.

3. Pulse Rate Change. The change in pulse rate equals the difference between the highest pulse rate reached during the tilt-up intervals and the average pulse rate of the 5 readings before tilt.

4. Smallest Pulse Pressure. The smallest pulse pressure is the smallest difference between systolic and diastolic blood pressure during the tilt-up interval.

5. Time to Smallest Pulse Pressure. This measure equals the number of minutes elapsing between the time when the subject was tilted up and the time at which the smallest pulse pressure occurred.

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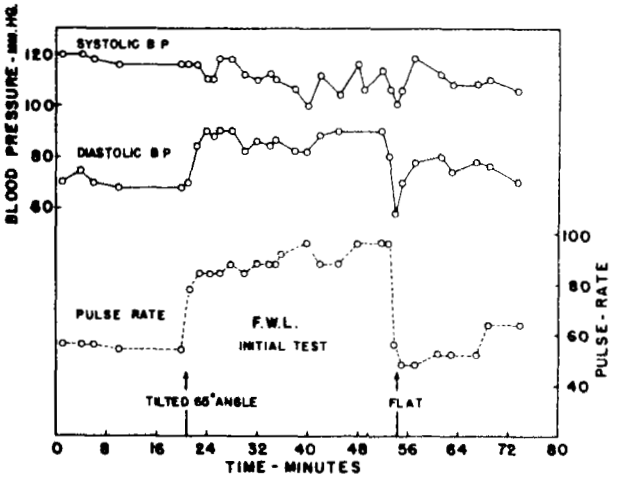
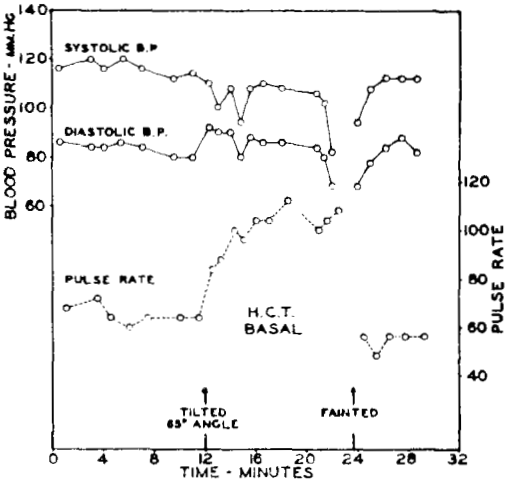
[22] Schneider, E. C. Physiology of muscular activity. Philadelphia, Pennsylvania: W. B. Saunders Company, 1933.

[23] Graybiel, A. and McFarland, R. A. The use of the tilt table test in aviation medicine. J. Aviation Med., 1941, 12, 1-20.

AVIATION CADET ON THE TILT TABLE (65° ANGLE)
DURING RECORDING OF BLOOD PRESSURE

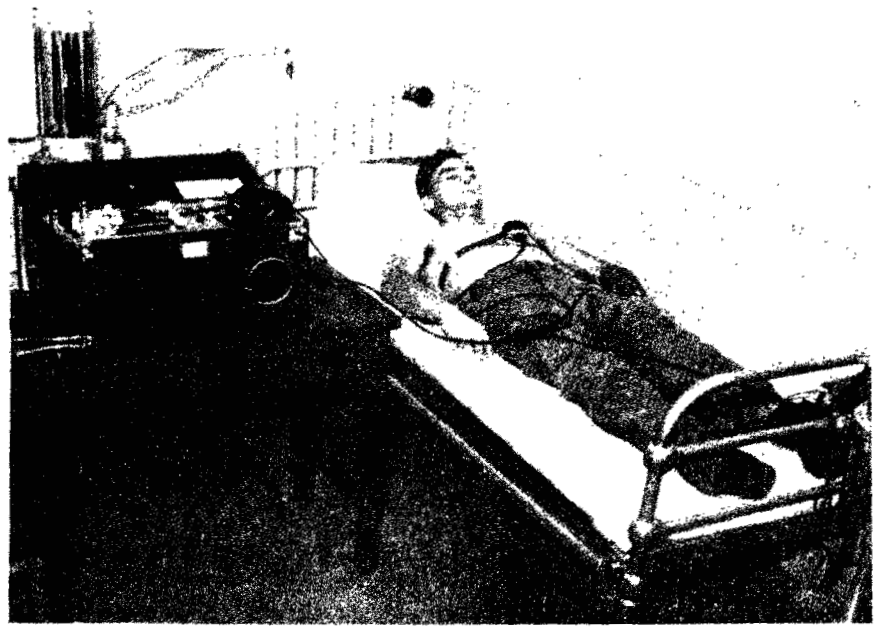
Figure 11



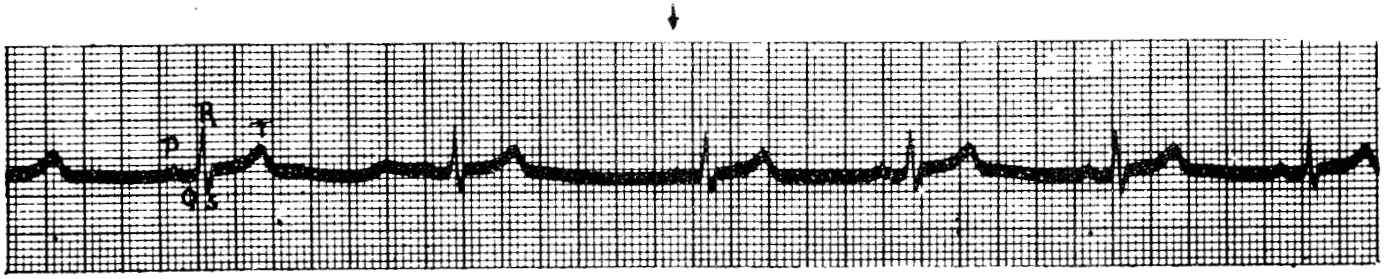


SAMPLE RECORDS OF SYSTOLIC AND DIASTOLIC BLOOD PRESSURE AND PULSE RATE OBTAINED ON AVIATION CADETS MAKING GOOD (A) AND POOR (B) RESPONSES ON TILT TABLE TEST

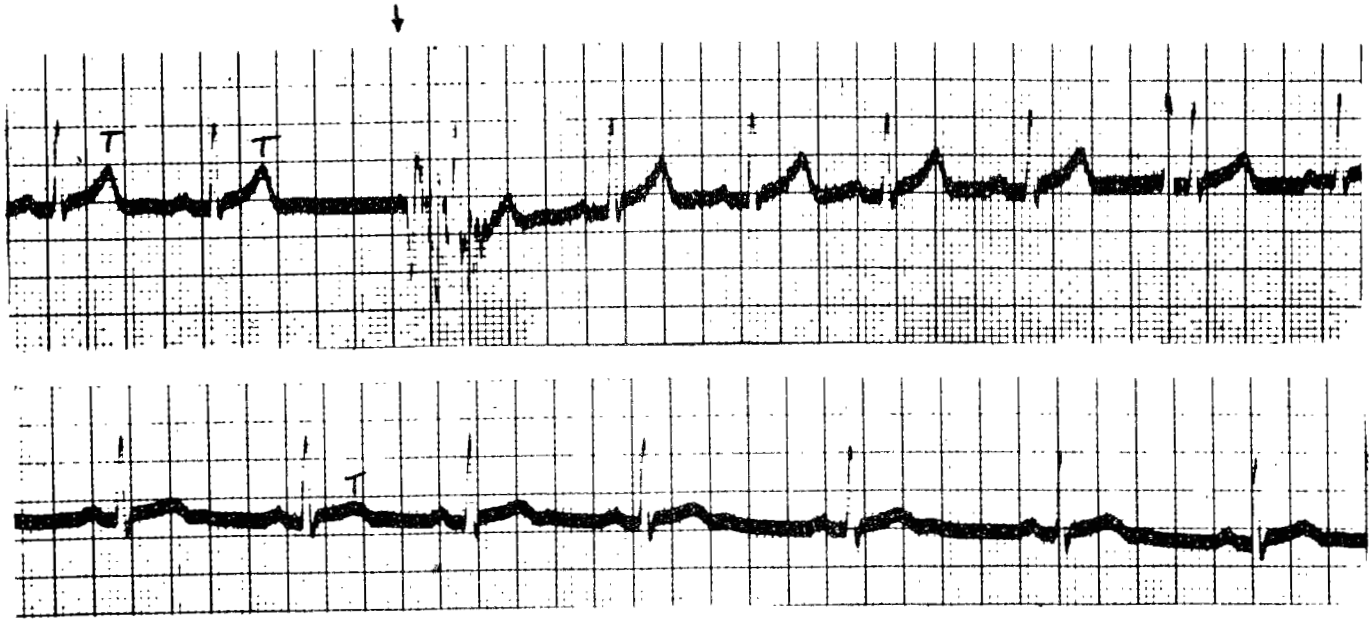
Figures 12A and 12B



RECORDING OF AN ELECTROCARDIOGRAM OF AN AVIATION CADET
Figure 13



NORMAL ELECTROCARDIOGRAM WITH ONLY SLIGHT RESPONSE TO STARTLE
Figure 14A



NORMAL ELECTROCARDIOGRAM WITH MARKED RESPONSE TO STARTLE
FOLLOWED BY LOWERING OF T-WAVES AND CHANGE IN PULSE RATE
Figure 14B

Sample records of pulse rate and blood pressure readings are shown in Figure 12A for a good response and in Figure 12B for a poor response (the response of a subject who fainted while on the table in a tilted position).

III. Electrocardiography, Response to Startle, and Circulatory Reflexes

Electrocardiography.[24] In normal heart action, a wave of excitation originating in the sino-auricular node (that region of the heart said to have the highest degree of irritability) precedes each wave of contraction. This wave then radiates out over the entire auricular musculature. It is then picked up by another structure in the heart, the atrio-ventricular node, and conducted over the bundle and its branches to the muscle cells of each ventricle. The velocity is relatively slow, i.e., about 1 meter per second in the auricles and approximately 3-4 meters per second in the bundle. The total time from the sino-auricular node to the ventricle, the P-R interval, is normally 0.12 to 0.20 seconds. During normal heart action, the auricles and ventricles function in a rhythmical, one-to-one sequence. In other words, in normal heart action, there is a wave of excitation over the auricles with the auricular systole, followed by the passage of the wave over the ventricles with the ventricular systole.

The electrocardiogram is an oscillographic record of the electrical changes which occur during a given series of cardiac cycles. The current from the heart is taken off indirectly by electrodes placed on the two arms (the so-called Lead I), on the right arm and the left leg (Lead II), on the left arm and left leg (Lead III), and on the precordium and one of the extremities or the junction of the three (Lead IV, and other chest leads). In this investigation a Sanborn portable cardiette was employed (see Fig. 13) and tracings were obtained for each candidate, using four of these leads. Under normal conditions, five different waves are identifiable on the records. Three of these, the P, R, and T waves, are positive; the other two, the Q and S waves, are negative. These latter two may sometimes be absent in the records. The Q, R, and S waves are usually referred to together as the QRS complex. Under normal conditions, the P-wave is associated with the auricular systole and the QRS complex with the beginning of the ventricular systole. The T-wave is associated with the height and end of the ventricular systole.

Response to Startle (pistol shot).[25] In the military services, it is well known that certain pilots are eliminated because of emotional instability or loss of control in emergency situations. The difficulties involved in developing an objective test which might predict inaptitude of this nature are apparent, especially in predicting from laboratory experiments what might actually take place under more realistic conditions in

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[24] Graybiel, A. and White, P. D. Electrocardiography in practice. Philadelphia, Pennsylvania: W. B. Saunders Company, 1941.

[25] Landis, C. and Hunt, W. A. The startle pattern. New York: Farrar & Rinehart, 1939.

flight. In the survey which was made of tests in this field, response to startle seemed to be worthy of further study. Henmon,[26] for instance, reported that tests of emotional stability involving the measurements of a series of reactions following the discharge of a pistol (i.e., amplitude of the tremors of the hand, time of recovery from tremor, changes of frequency in the pulse rate, changes in the frequency and the amplitude of respiration) gave the highest correlation in a series of other tests with aptitude for flying.

In this study the subject was attached to the basal metabolism apparatus and to Lead II of the electrocardiograph. A gun was fired without the subject's foreknowledge. An analysis was then made of the alterations observed in somatic tremor, the spirogram, and the electrocardiogram. The following scores were recorded for change in heart rate:

1. Average control rate before the startle expressed as the average heart rate for 6 seconds before the startle.
2. Average heart rate 0-6 seconds after the startle.
3. Average heart rate 6-12 seconds after startle.
4. Average heart rate 12-18 seconds after startle.

Three measures of somatic tremor were taken following the startle:

1. Total duration expressed in seconds.
2. Initial amplitude expressed in millimeters.
3. Amplitude 3/5 seconds after the startle expressed in millimeters.

For the alteration in T-waves, the following scores were taken:

1. Time of onset expressed in seconds.
2. Maximum change in amplitude expressed in millimeters.
3. Persistence of change in T-waves expressed in seconds.

Illustrations of what might be considered a good and a poor response are shown respectively in Figures 14A and 14B. In the former, there was no change in the electrocardiographic tracing, while in the latter there was considerable somatic tremor, followed by an increase in heart rate and a marked lowering of the T-wave.

Carotid Sinus Sensitivity. It is well known that pressure over the bifurcation of the common carotid artery in the neck may produce a sensation of faintness, accompanied by slowing of the pulse rate and fall in systolic blood pressure. These changes take place reflexly, and the magnitude of the response varies a great deal among individuals. It was believed that testing for the presence of abnormal carotid sinus sensitivity might prove worthwhile. The procedure was as follows: the subject was seated, attached to an

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[26]Henmon, V. A. C. Air service tests of aptitude for flying. J. Appl. Psychol., 1919, 3, 103-109.

electrocardiograph, and with blood pressure cuff in position. Following two initial blood pressure readings, a physician massaged the carotid sinus in the neck. Additional readings were made 30 seconds after pressure on the right carotid artery and 30 seconds after pressure on both carotid arteries. Electrocardiographic tracings were obtained at standard intervals during the experiment.

Cold Pressor Test. This test was included to evaluate each cadet's blood pressure response to a standard painful stimulus.[27] Each cadet was given this test in Part I of the study. After the blood pressure was stabilized, the right hand was immersed in a pail of ice water for one minute. The raw score for the greatest systolic change was the difference between the systolic blood pressure before placing the right hand in ice water and the point at which the systolic pressure was highest during the 60-second period of immersion. The greatest diastolic change was the difference between the diastolic pressures obtained in a similar manner. In a small number of cases, electrocardiographic tracings were also obtained during this test.

Skin Resistance. The galvanic skin response or psychogalvanic reflex was included as one of the tests because of its possible value in revealing emotional reactions.[28] A selected number of cadets was given this test: 97 successes, 15 washouts, and 7 board appearances. The usual procedures in studying this reflex were used. One electrode was attached to the arm, and one recording electrode to the third finger of the right hand. The tests were carried out in the late afternoon when there were no distractions in the laboratory, or in the area, such as a large number of aircraft flying overhead. After a base line in the galvanic response was determined and a number of readings recorded, the hand was placed in ice water for 30 seconds. Successive readings were taken during the recovery period, and the subject's response indicating pain, or when pain disappeared, was tabulated. After an interval of time, the subjects were asked questions relative to their difficulties in flying or other emotionally tinged questions, such as about illnesses or deaths in the family, about their fiancees, or about questions from the medical history which the physician obtained during a previous interview. Interest centered on whether the cadets who had failed their flight training course would have more extreme responses than those who were successful.

IV. Electroencephalography and Anthroposcopic Studies

Electroencephalography (Brain waves - Grass apparatus).[29, 30] This test was given in order to observe such differences as might exist in brain waves

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[27] Hines, E. A., Jr. and Brown, G. E. A standard stimulus for measuring vasomotor reactions. Proc. Staff Meet., Mayo Clin., 1932, 7, 332.

[28] For review of the work in this field, see: Woodworth, R. S. Experimental Psychology. New York: Henry Holt & Co., 1938, Chap. 13.

[29] Davis, P. A. Technique and evaluation of the electroencephalogram. J. neurophysiol., 1941, 4, 92-114.

[30] Gibbs, F. A. and Gibbs, E. L. Atlas of electroencephalography. Cambridge, Massachusetts: The L. A. Cummings Company, 1941.

between the successful and the unsuccessful pilots in flight training. In addition, interest centered in its value as a clinical measure for the detection of cadets with epileptoid trends, brain tumors, or brain injuries. The electroencephalogram is a record of the electrical activity of the brain, consisting of trains or spurts of waves possessing definite characteristics with regard to frequency, amplitude, and shape. The electric potentials from the brain are picked up and greatly amplified and recorded by an automatic pen marker (see Fig. 15). Essentially the same principle is involved in studying the electrical activity of the brain as is the case with the electrocardiograph for the electrical activity of the heart. Records were obtained on each cadet in the recumbent position with the eyes open, and again while the eyes were closed. At the end of the test, each cadet was asked to hyperventilate (breathe very deeply and rapidly) to the beats of the metronome. A graphic record of the breathing was recorded with the spirometer. Four EEG measures were analyzed in this investigation: (1) Alpha Index, the average of the left and right scalp leads representing the number of centimeters in a standard length of record; (2) Alpha Frequency, ranging in frequency from 7 to 14 cycles per second; (3) Voltage, the average amplitude of right and left scalp leads; and (4) the presence or absence of abnormalities expressed as ratings on a scale varying from 1, the best, to 4, the poorest score.[31] Great care was taken in obtaining these records to make certain that the subjects did not become drowsy or fall asleep.

Body Build (somatotype - Sheldon's method).[32, 33] Each cadet was photographed in a standardized manner in the nude from the front, back, and side positions (see Fig. 17). From these photographs, a series of measurements were made which collectively revealed the underlying physical constitution of the individuals. The composite score for each cadet consisted in rating each of the three "components" of structure, described as "primary" aspects of body constitution; i.e., (1) endomorphy, dominance of visceral structure or soft roundness of body regions; (2) mesomorphy, corresponding to the athletic type of build or dominance of bone and muscle; and (3) ectomorphy, dominance of "linearity" and "fragility," especially the nervous system and sense organs. The actual photograph of a cadet with a 4-5-2 rating and dysplasia = 0 is shown in Fig. 18. The anthroposcopic method was used in this study. It consists in somatotyping five regions by inspection: (1) head and neck, (2) upper trunk (above the diaphragm), (3) arms, (4) lower trunk (below the diaphragm), and (5) legs. This procedure differs from the anthropometric method, wherein about fourteen exact measurements are made. A very high correlation exists between the two methods. In the somatotype, the first numeral refers to total endomorphy, the second to mesomorphy, and the third to

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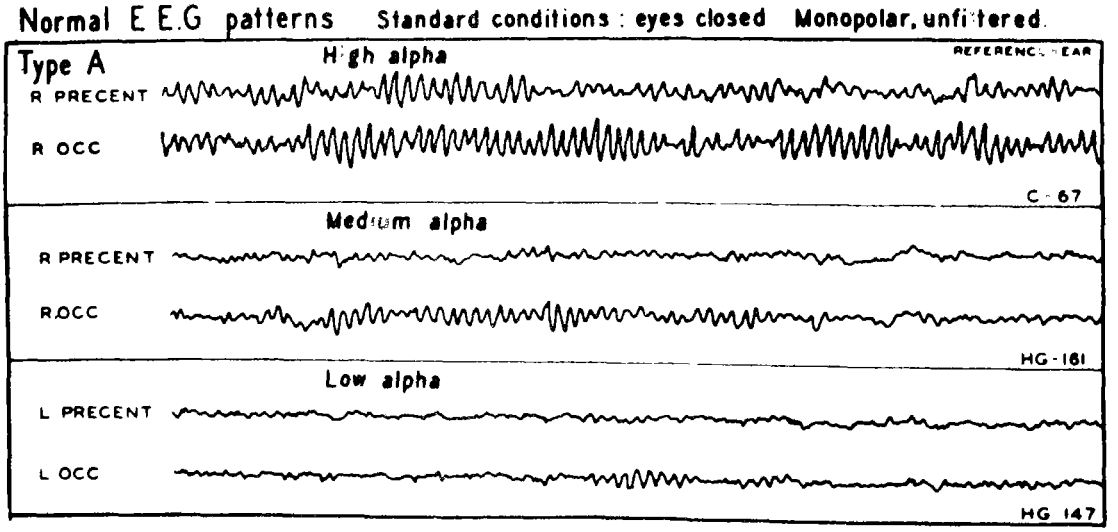
[31] A further discussion of these measures may be found in: Forbes, A. and Davis, H. Electroencephalography of Naval Aviators. Washington, D. C.: C.A.A. Division of Research, Report No. 13, April 1943.

[32] Sheldon, W. H., Stevens, S. S., and Tucker, W. B. The varieties of human physique. New York: Harper & Bros., 1940.

[33] Sheldon, W. H., and Stevens, S. S. The varieties of temperament. New York: Harper & Bros., 1942.

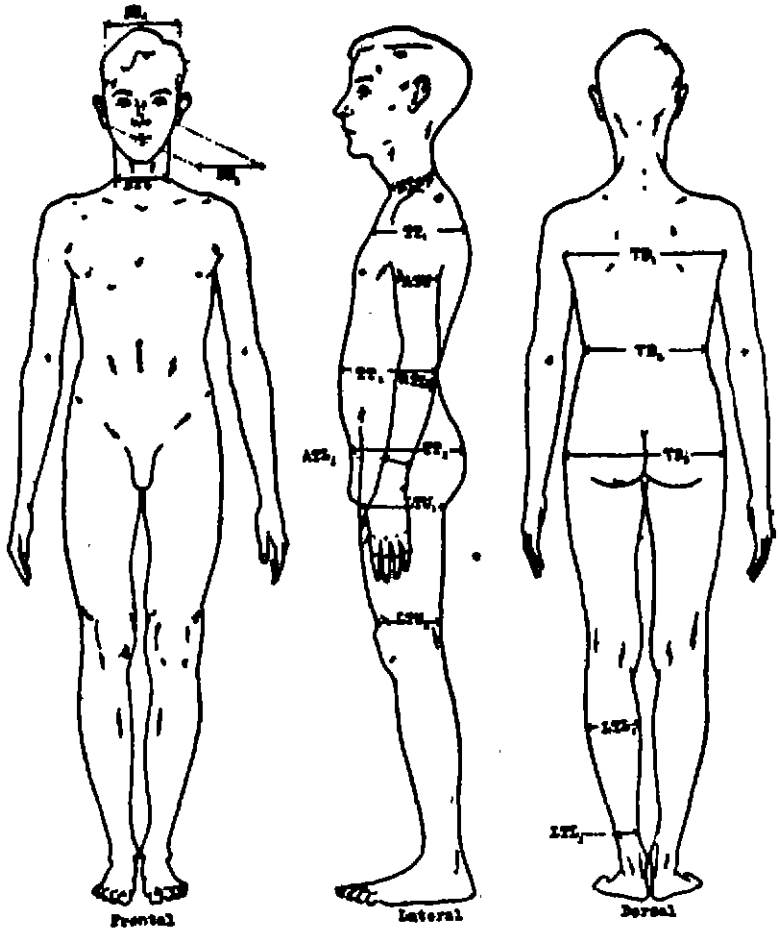
THE AMPLIFIERS AND AUTOMATIC PEN RECORDERS USED IN THE RECORDING OF ELECTROENCEPHALOGRAMS (BRAIN WAVES)

Figure 15



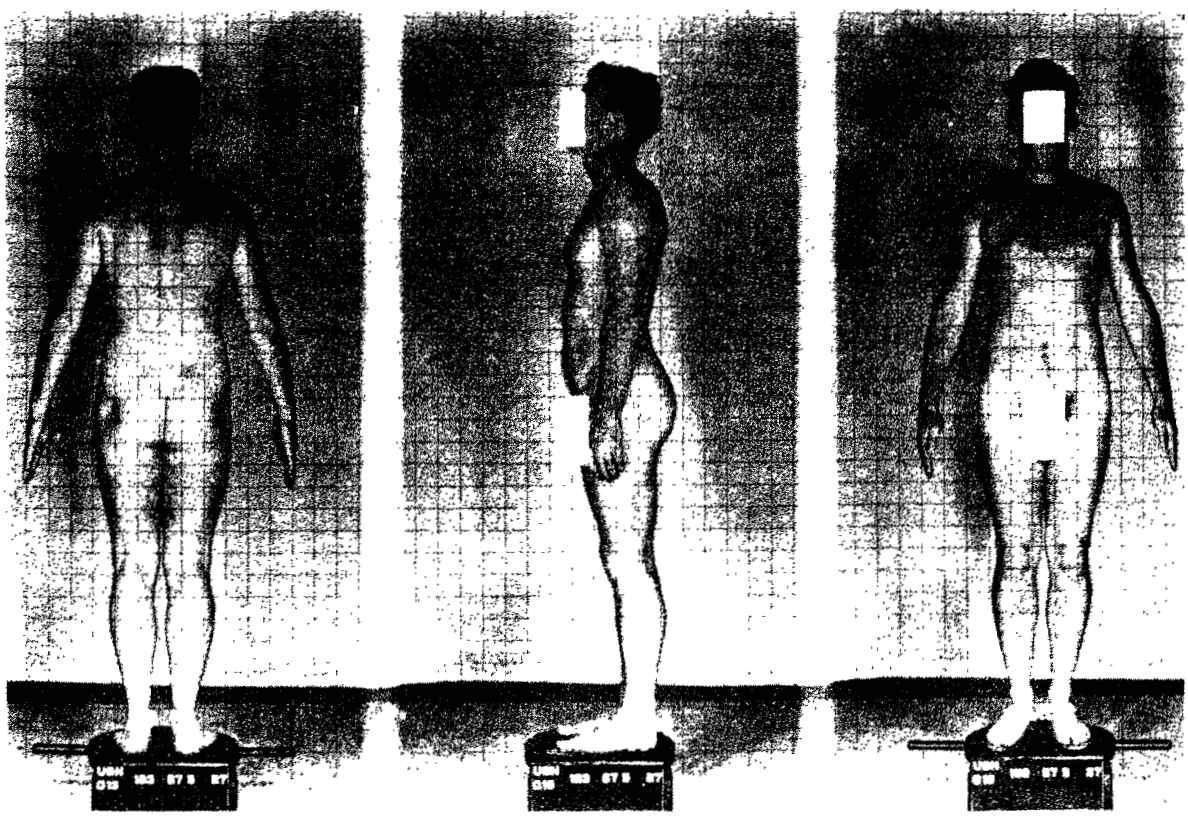
BRAIN WAVE PATTERNS TYPICAL OF THOSE COMMONLY OBSERVED IN NORMAL PERSONS

Figure 16



VARIOUS POSITIONS IN WHICH EACH CADET WAS PHOTOGRAPHED
IN THE NUDE TO OBTAIN RECORDS FOR SOMATOTYPING AND DYSPLASIA

Figure 17



ACTUAL PHOTOGRAPH OF A CADET TAKEN IN VARIOUS POSITIONS
TO OBTAIN THE SOMATOTYPE AND DYSPLASIA RECORD

Figure 18

ectomorphy. In the somatotyping procedure, each of these three primary components is classified on a seven-point scale. An inspectional estimate of the strength of each component is made from an examination of a photograph of the subject. Numerals are assigned to each physique, including one for its position on the scale for each component. Thus, the physique of an individual classified as a 7-1-1 is extreme in endomorphy and at a minimum in the other two components. The 4-4-4 is an individual about at the mid-point of all three scales. The pattern of the three elemental morphological components, as expressed by the three numerals, represents the individual's "somatotype." The photographs were also scored for dysplasia, a term used to signify "disharmony between different regions of the same physique." When, for example, a physique is of one somatotype in the region of the head and neck, and of another somatotype in the legs or trunk, the individual is spoken of as dysplastic. Dysplasia is measured by totaling the differences among the somatotype designations for five regions of the body.

TEST ADMINISTRATION PROCEDURES

The testing program was organized so that each cadet was assigned to the Research Laboratory for one full day as an official part of his indoctrination into the Naval Air Station. This assignment occurred during the first week before any flight training. Each cadet had passed a solo flight test and each had had ten hours of dual instruction at one of the elimination bases located in 12 different parts of the United States. Only a few trainees had had more than 10 hours of flight time before their entrance at Pensacola. From the official and routine nature of the program, the cadets were led to believe that their results in the tests would become an official part of their records. The motivation was high and the cooperation excellent throughout the study.

Each class of cadets of approximately 50 took the Otis Mental Test, the Minnesota Paper Form Board Test, and the Athletic Achievement Test as a group in a classroom at the cadet barracks. The first test took 20, the second 30, and the third about 15 minutes. There was no time limit on the Athletic Achievement Test.

Subjects came to the Laboratory in groups of four at 6:00 a.m., 7:30 a.m., and 8:00 a.m. Each subject received a typed statement several days before taking the tests, which gave a brief account of the purpose of the tests, and the time and place to report. These typed statements gave specific instructions indicating the amount of rest and the avoidance of alcohol and tobacco on the previous night, with no food or exercise on the morning of the tests, in order to provide optimal conditions for the basal metabolism test.

Partitions were constructed in the building assigned for the Laboratory to permit the various tests to be given in separate rooms, thus avoiding distractions. Four sets of metabolism and electrocardiographic apparatus were available so that four subjects could be studied simultaneously.

After the cadets had reclined on the beds for 30 minutes, they were given the basal metabolism and breathing tests - two eight-minute records.

They then breathed against the resistance (Page 12), and vital capacity determinations were made. After a short rest, they were connected with the electrodes on the electrocardiograph, and records were obtained with four different leads. While still attached to the breathing apparatus and electrocardiograph, a very loud pistol shot was fired in the room, at a time unknown to the cadets, to obtain records of response to startle. They were then given the Schneider Index and Tilt Table Tests. Then each cadet was served a light standard breakfast in the Laboratory. Following this meal they were scheduled through the special rooms in routine fashion for the various psychomotor tests, the brain wave, somatotyping, aniseikonia, night vision test, and the response to the carotid sinus sensitivity, salt tablet, and skin resistance experiments. During rest periods they filled out the questionnaire relating to medical history, education, and aviation interests. The interviews were given by a physician in the afternoon. If the results of the metabolism, brain waves, or electrocardiography were not satisfactory they were recalled for retests as soon as convenient. In certain instances it was not possible to recall them and there are, therefore, slight variations in the number of subjects tested (see Tables 3-8).

It was not possible to control the temperature in the laboratory rooms, although electric fans were used to circulate the air. The mean temperature during the summer months, when the data of Part I were collected, remained fairly constant. In the fall and early winter (data for Part II) the temperature was cooler. The differences in climate during the two parts of the study were not extreme, but this variation might have given rise to certain differences in the respiratory and circulatory tests.

The psychomotor tests were given in the same order as listed on pages 5 and 6. Each subject received standardized instructions[34] and appropriate practice periods before taking each test.

All of the tests were recorded on standardized forms and scored at Pensacola. The material was then sent to Harvard where all of the tests were checked and rescored. In the case of specialized tests, such as the interpretation of the electrocardiograms, the work was directed by authorities in each field; for instance, the scoring of the electrocardiographic material was directed by Ashton Graybiel; the electroencephalographic records by Hallowell Davis and Alexander Forbes; the somatotyping by Wm. H. Sheldon; and aniseikonia by A. Ames, K. Ogle, and Robert H. Peckham.

CRITERIA

Early in the research program it was apparent that one of the most difficult problems in evaluating the various tests centered around criteria of

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[34]The standardized instructions to those tests were presented orally by the examiner. Detailed instructions for the Two-Hand Coordination Test and the Cashburn Postural Motion Test may be found in the Appendices to the separate reports on these tests (see footnotes 7 and 43). Directions for the MacDougall Dotting Test may be found in MacDougall, R. and Smith, W. D. [illegible]

success or failure in flying. In other words, it was necessary to have reliable and, preferably, objective data relating to successful performance in flight training to correlate with the tests. In an attempt to obtain reliable indices of aptitude for flying, an analysis was made of the instructors' comments and ratings in the flight jackets of over 50 cadets who had failed, in comparison with a group who had passed the course at Pensacola. This analysis of the flight jackets showed that the instructors did not stress the same variables in rating flight performance. Some placed more emphasis on one factor than on another, making it difficult to rank the pilots. If adequate analytic measures of each pilot's aptitude were available, such a variable as poor coordination in handling the plane might be correlated with a low score in one or more of the psychomotor tests; poor landings in small fields with faulty space perception; or poor judgment with tests of mental ability. Not only were the numerical records in the flight jackets relating to various phases of flying based on widely differing criteria, but also the range was not great enough in the various scores (0 - 4) to be meaningful for evaluating various faults in relation to scores on specific tests. The large majority of the ratings was 3.

The next approach was to tabulate the comments on causes of failure in the flight jackets of pilots who had been dropped from training. With these data as a background, a printed form was drawn up (see Appendix C) which described certain characteristics of flying, such as perception and control of the plane's position, coordination of controls, and mental performance for each stage of flight training, both primary and advanced. A code was drawn up so that the records would indicate whether the defect at the time a pilot was taking a check flight was made on approaches, taxiing, take-offs, climbing, gliding, or landing (see code at left-hand side of printed form). This form was filled out for a number of washouts not in the present study, as well as for those cadets who failed in Part I. On the basis of these data, it was possible to determine whether the chief cause of failure was poor "headwork" while training, roughness at the controls, or poor coordination and certain other general categories of flying faults. It was not possible, however, to translate this information into a numerical score for purposes of correlation. Furthermore, the instructors were not trained in rating each pilot on the basis of similar criteria. This lack of common basis for rating gave widely varying results, depending on the conscientiousness of each instructor or on his particular emphasis in grading flying faults.

A further attempt was made by Dr. A. H. Peckham to devise a flight score based on the number of possible flights and rechecks, as recorded in the flight jackets. There were 35 possible flight checks and rechecks in primary land planes, all of which may or may not have been flown. Thus, the flight score was 35 possible checks minus the number of checks actually flown or assumed flown unsatisfactorily. If the trainee passed his first check flights at each stage of training, he would have flown a total of 5 flights, and it may be assumed, therefore, that the remaining 30 checks would have been flown satisfactorily. If he failed the first two of the three checks at any stage, it was assumed that his third would also have been failed. If a student was dropped from flight training for any reason, all checks following his stage of drop were regarded as unsatisfactory. On the basis of this procedure, scores were obtained for all of the pilots tested in Parts I and II of this study.

From these scores it was possible to differentiate the successes from the failures as a group, due to the resulting high score of those who passed the largest number of flight checks. The critical ratios between the successes and washouts were highly reliable, as might be expected. On the other hand, there are serious limitations in this scoring method, i.e., many of the washouts received high scores simply because they passed a large percentage of the flight checks and rechecks before being dropped. Therefore, those students who remain at Pensacola the longest time, regardless of whether they eventually pass or fail, will receive the highest scores. Following an analysis of all of these factors, it was decided to use the absolute standard pass-fail as the criterion of flight performance.

Prior to 1939 approximately 30% to 35% of the cadets accepted for flight training failed in either primary or secondary flight training at Pensacola. During the months just before and during the present study, however, there was a marked drop in the percentage of candidates eliminated. An analysis of "attrition" in flight training before and during the course of this study was thus made from records in the Training Department at Pensacola Naval Air Station.

The analysis (see Table 2 and Figure 19) begins with Class 128 which entered in July, 1939. It is obvious that the frequency of failure decreased in striking fashion.[35] The majority of the failures occur during the training period in primary land planes. The attrition in advanced training has nearly disappeared. This decrease in the percentage of failure in each class made the determination of the predictive value of the various tests more difficult. The investigation was therefore continued over a longer period of time than was originally planned in order to obtain test results for a larger number of washouts. The percentage of failures remained at approximately 10% to 15% throughout the latter part of the study.

The main criterion for success in flying was based simply on whether the candidate passed or failed the course in Primary Training. The subjects have been classified into four groups as follows (the words "successful" and "good pilots" do not have a specific connotation other than that indicated by the definitions below):

1. Good Pilots. Those successful pilots who had never appeared before the Commandant's Advisory Board.

2. Successes. All pilots who passed in flight training, including those who had appeared before the Commandant's Advisory Board during their training as well as those who had not.

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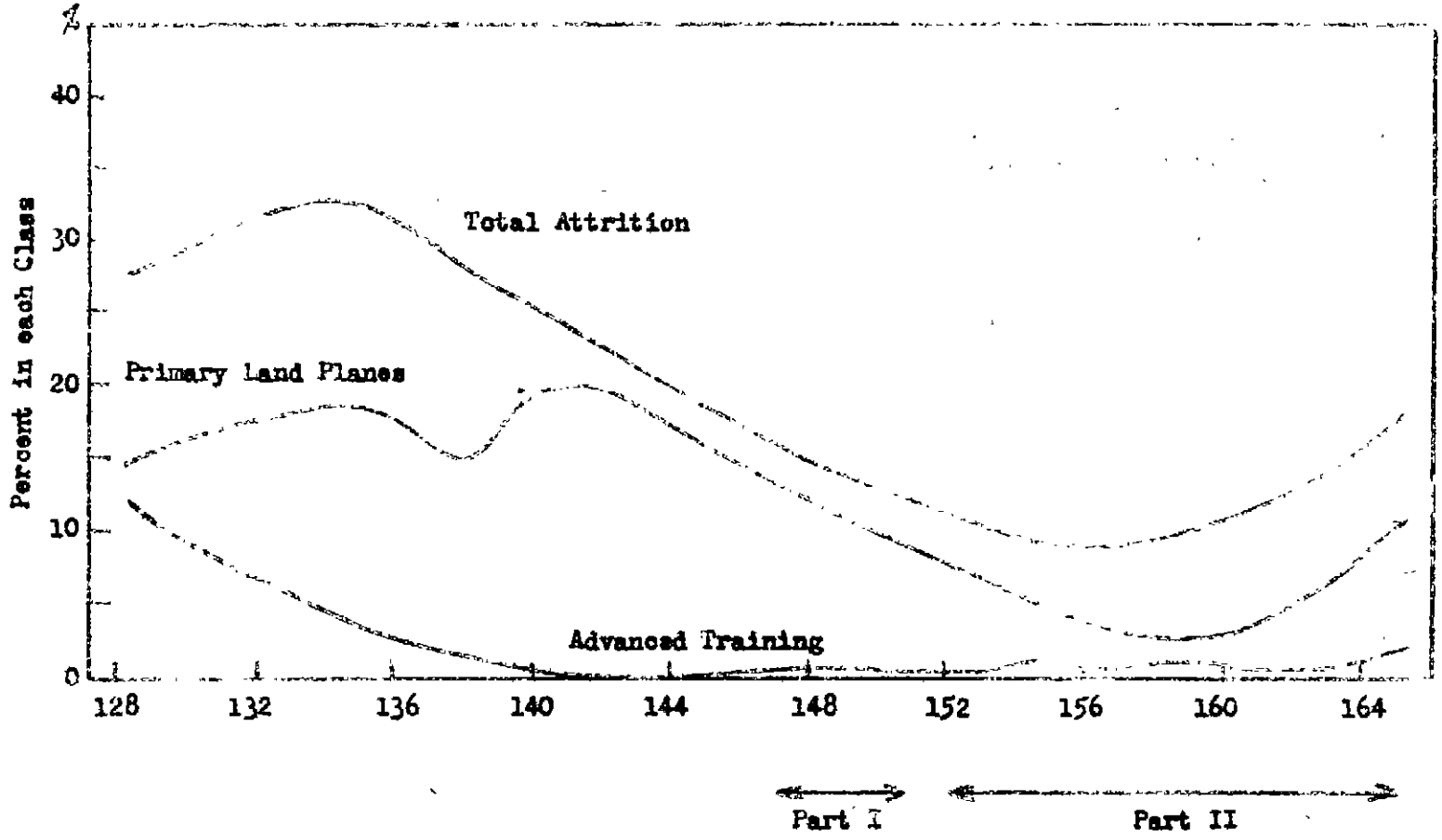
[35] This decrease in the frequency of failure may be attributable to various causes. In the first place, the methods of instruction may have been improved by the introduction of a new syllabus for flight training in July, 1939. In the second place, it is possible that the Selection Boards may have picked a higher type of candidate. Also, in the first group studied in this program there were 88 officers from the Naval Academy, known to be carefully selected on the basis of intelligence, personality, and officer-like qualities. Only a few of these men were dropped from training. Finally, it may be that the war influenced the Training Department to spend more time with the poorer cadets in the hope of having a larger number complete the course.

TABLE 2

ANALYSIS OF ATTRITION
PERCENTAGE OF FAILURES IN FLIGHT TRAINING IN CLASSES 134 to 165

Class Number	No Cadets	No Officers	Enlisted Men No	Total Number in Class No	Total Attrition %	Failed - Primary Training %	Failed - Advanced Training %	Failed - Ground School %	Dropped - Disciplina %	Dropped - Own Request %	Killed in Flight %	Not Physically Qualified %
134	55	0	0	55	30.9	21.8	3.6	5.5	0.0	0.0	0.0	0.0
135	51	0	0	51	23.5	7.8	0.0	0.0	3.9	0.0	0.0	11.8
136	51	0	0	51	41.2	29.4	0.0	7.8	2.0	0.0	0.0	2.0
137	48	15	0	63	22.2	17.4	0.0	1.6	0.0	0.0	0.0	3.2
138	34	15	0	49	26.5	20.4	0.0	2.0	4.1	0.0	0.0	0.0
139	36	16	0	52	21.2	17.4	0.0	1.9	0.0	0.0	1.9	0.0
140	32	0	0	32	25.0	12.5	0.0	0.0	6.3	0.0	3.1	3.1
141	18	16	0	34	11.8	2.9	0.0	0.0	2.9	2.9	0.0	2.9
142	23	0	15	38	34.2	21.1	0.0	0.0	7.9	2.6	0.0	2.6
143	22	0	13	35	22.8	11.4	0.0	0.0	5.7	0.0	0.0	5.7
144	20	0	15	35	28.6	17.1	0.0	0.0	5.7	2.9	2.9	0.0
145	18	15	16	49	14.3	6.1	0.0	2.0	2.0	2.0	2.0	0.0
146	52	0	0	52	25.0	15.4	0.0	0.0	0.0	5.8	1.9	1.9
147	58	30	0	88	13.6	8.0	0.0	1.1	0.0	2.3	0.0	2.3
148	57	19	0	76	10.5	4.0	0.0	0.0	2.6	1.3	0.0	2.6
149	56	20	0	76	10.5	2.6	1.3	0.0	1.3	1.3	1.3	2.6
150	58	19	0	77	11.7	6.5	0.0	0.0	1.3	0.0	1.3	2.6
151	59	19	0	78	10.2	9.0	0.0	1.3	0.0	0.0	0.0	0.0
152	53	17	0	70	7.2	2.9	0.0	0.0	0.0	2.9	0.0	1.4
153	59	4	0	63	22.2	14.3	0.0	0.0	3.2	3.2	1.6	0.0
154	80	9	0	89	12.4	5.6	2.2	0.0	2.2	0.0	1.1	1.1
155	70	0	19	89	9.0	3.4	1.2	1.2	0.0	2.2	0.0	1.2
156	108	0	19	127	9.4	6.3	0.0	0.0	0.8	0.8	0.8	0.8
157	84	0	19	103	5.8	2.9	1.0	0.0	0.0	1.9	0.0	0.0
158	86	0	15	101	10.9	3.0	2.0	0.9	0.9	2.0	0.0	2.0
159	85	0	14	99	3.0	1.0	0.0	0.0	0.0	1.0	0.0	1.0
160	84	0	20	104	9.6	2.9	1.0	1.9	1.0	1.0	0.0	1.9
161	104	4	15	123	17.1	8.1	0.8	0.0	0.8	2.4	0.0	4.8
162	105	0	14	119	16.0	8.4	0.0	0.0	0.0	1.7	2.5	3.4
163	113	16	20	149	14.8	4.7	0.7	0.0	0.0	4.7	0.7	4.0
164	118	15	14	147	15.6	4.1	2.0	0.0	1.4	5.4	2.0	0.7
165	120	0	0	120	18.3	10.0	1.0	0.8	0.0	4.2	0.8	1.5



Classes at Pensacola

ANALYSIS OF ATTRITION

3. Board Appearances. All pilots who had difficulties in flight training and appeared before the Commandant's Advisory Board. (Note that this group includes only those pilots who appeared before the Advisory Board and were passed.)

4. Washouts. All pilots eliminated from flight training for poor aptitude, not including those who dropped from training because of poor health, for disciplinary reasons, or for getting married.[36]

RESULTS

The results will first be presented in summary form in order to indicate the major findings. Following the summary presentation, the results obtained on each test in the battery will be discussed. As mentioned on page 2, it seemed advisable to divide the data into Parts I and II because of the differences in the populations studied and in the experimental conditions under which the tests were administered. Part I refers to classes 147-151, in which there was a large proportion of college students. Part II data are on classes 152-161, in which many of the cadets had only a high school education.

Summary Results

Tables 3 and 4 present the means and standard deviations for each of the tests with the subjects grouped according to the criterion classifications described above. Tables 5 to 8 present critical ratios of the differences between means and P-values based on chi-square comparisons between the criterion groups. Comparisons presented are between (a) Successes versus Washouts and (b) Good Pilots versus Washouts plus Board Appearances.

An examination of Table 5 shows that in a group of psychological tests the following have a critical ratio of 3.0 and above, or a P-value of 0.01 or less, or both, in either Part I or Part II, with the other Part not inconsistent: (1) Otis Test of Mental Ability, (2) Eye-Hand Coordination Test, (3) Two-Hand Coordination Test, (4) Washburn Serial Action Test. This shows that these tests offer promise for selection purposes. Other psychological tests (e.g., Minnesota Paper Form Board, McDougall Dotting Test, and Ataxiameter) used in this experiment do not show a significant difference between washouts and successful candidates, either by interpretation of the significance of the difference of the means or by interpretation of the P-value of the chi calculation.

Table 6, which shows the distinction between good pilots versus washouts plus board appearances, again selects the three psychomotor tests cited above, though the result on the Otis Test is not as good. The mechanical aptitude (Minnesota Paper Form Board) test shows a low P-value in this table for Part I, but there is no significant difference between the selected

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[36] An interesting analysis of the specific reasons for failure, as determined by an interview held just prior to the cadet's appearance before the Commandant's Advisory Board, is presented in Appendix D.

TABLE 3

PSYCHOLOGICAL TESTS - MEANS AND STANDARD DEVIATIONS

Tests and Interpretations	Groups	Part I (classes 147-151) N	Mean	Sigma	Part II (classes 152-165) N	Mean	Sigma
Mental Ability (Otis Higher): High score indicates superior performance.	Good Pilots	273	52.6	8.6	264	45.8	9.2
	Successes	309	52.3	8.9	349	45.2	9.3
	Wash.& B.A.	65	48.7	10.0	186	43.1	10.6
	Washouts	33	47.2	9.4	101	42.3	11.6
Mechanical Aptitude (Minn. Form Board): High score indicates superior performance.	Good Pilots	278	43.7	7.8	237	42.9	8.4
	Successes	306	43.5	8.0	321	42.9	8.3
	Wash.& B.A.	63	40.8	9.0	185	41.6	9.1
	Washouts	35	40.7	8.4	101	40.9	9.6
Athletic Achievement (Thorndike-Keller): High score indicates superior performance.	Good Pilots	293	45.2	22.0	Test was not given in Part II.		
	Successes	318	45.1	21.9			
	Wash.& B.A.	62	39.7	22.9			
	Washouts	37	36.8	21.9			
Eye-Hand Coordination: Score is based on the mean of 8 trials; low score indicates superior performance.	Good Pilots	303	69.8	8.3	97	69.7	9.6
	Successes	336	69.8	8.1	114	69.8	9.8
	Wash.& B.A.	70	71.9	6.7	88	73.4	8.4
	Washouts	37	73.2	6.4	71	74.0	7.6
Two-Hand Coordination: Score is based on the mean of 4 trials; low score indicates superior performance.	Good Pilots	303	57.9	11.9	270	68.5	12.2
	Successes	337	58.0	12.0	321	68.7	11.9
	Wash.& B.A.	73	63.4	12.1	140	72.0	11.3
	Washouts	39	67.3	9.8	89	73.3	11.9
Washburn Serial Action Test: Score is expressed in minutes; low score indicates superior performance.	Good Pilots	303	5.8	0.9	323	5.6	1.1
	Successes	335	5.8	1.0	366	5.7	1.1
	Wash.& B.A.	72	6.5	1.2	120	6.1	1.2
	Washouts	39	6.7	1.2	77	6.2	1.3
Dotting Test (McDougall): Score is based on the mean 3 trials; high score indicates superior performance.	Good Pilots	300	216.5	26.3	350	208.9	24.7
	Successes	333	215.7	26.9	432	209.2	23.8
	Wash.& B.A.	70	208.8	26.0	174	207.6	24.3
	Washouts	37	202.5	20.7	92	205.1	27.6
Continuous Reaction Time (Cattell):							
Part A - The Slow Strip: High score indicates superior performance.	Good Pilots	273	430.3	82.4	Test was not scored in Part II.		
	Successes	308	427.8	81.2			
	Wash.& B.A.	62	395.0	76.4			
	Washouts	32	386.5	84.8			
Part B - The Fast Strip: High score indicates superior performance.	Good Pilots	275	325.6	78.8	Test was not scored in Part II.		
	Successes	305	322.6	78.4			
	Wash.& B.A.	62	289.4	75.6			
	Washouts	32	284.2	82.0			

TABLE 3 (continued)

Tests and Interpretations	Groups	Part I (classes 147-151) N	Mean	Sigma	Part II (classes 152-165) N	Mean	Sigma
Parts A and B: High score indicates superior performance.	Good Pilots	272	763.7	143.3	Test was not scored in Part II.		
	Successes	302	758.0	141.8			
	Wash.& B.A.	60	698.0	134.6			
	Washouts	30	690.8	148.3			
Ataxiameter (Miles): Amount of body sway in millimeters. Low score is favorable. Mean of 2 readings with eyes closed.	Good Pilots	304	438.8	118.6	329	404.1	112.9
	Successes	337	441.9	118.6	416	407.1	110.2
	Wash.& B.A.	68	452.7	107.2	190	416.3	109.6
	Washouts	35	435.5	96.3	103	414.6	118.8
Aniseikonia:							
Eikonometer: Score is sum of size diff. and size limits in either the horizontal or vertical meridians.	Good Pilots	218	1.7	1.6	Test was not given in Part II.		
	Successes	245	1.7	1.6			
	Wash.& B.A.	60	1.6	1.6			
	Washouts	33	1.6	1.6			
Leaf Room: Score is the sum of the response score and the plane lens test score.	Good Pilots	206	4.3	2.7	Test was not given in Part II.		
	Successes	232	4.3	2.7			
	Wash.& B.A.	58	3.9	2.3			
	Washouts	32	3.7	2.3			
Frontal Plane Apparatus: Score is sum of curvature determined by rods; response to distortion of lenses; scatter of data and its displacement from normal; response to cycle incongruities and to various eye lenses.	Good Pilots	81	2.6	1.6	Test was not given in Part II.		
	Successes	97	2.6	1.7			
	Wash.& B.A.	30	2.3	1.9			
	Washouts	14	2.3	1.4			
Photographs of Eye Movements (Ophthalmograph): Score is the number of visual fixations per line. Low score is favorable.	Good Pilots	289	8.4	1.7	Test was not given in Part II.		
	Successes	318	8.4	1.8			
	Wash.& B.A.	61	8.3	1.8			
	Washouts	32	8.2	1.4			
Dark Adaptation (Wald): Score is mean of 4 readings in micromillilamberts. Low score is favorable.	Good Pilots	Test was not given in Part I.			65	2.07	0.18
	Successes				143	2.06	0.18
	Wash.& B.A.				169	2.08	0.19
	Washouts				91	2.10	0.23
Perception of Change in Position: Score is mean of 8 trials. Low Score is favorable.	Good Pilots	304	23.4	9.7	335	19.6	7.8
	Successes	337	23.6	9.6	423	19.4	8.2
	Wash.& B.A.	70	24.1	8.2	194	18.4	8.3
	Washouts	37	23.6	7.6	106	18.3	8.2

TABLE 4

PHYSIOLOGICAL TESTS - MEANS AND STANDARD DEVIATIONS

Tests and Interpretations	Groups	Part I (classes 147-151) N	Mean	Sigma	Part II (classes 152-165) N	Mean	Sigma
Basal Metabolic Rate: Normal range lies between +15 and -15. Based on two runs of 8 minutes duration.	Good Pilots	298	+0.8	12.7	308	-3.9	10.0
	Successes	328	+0.5	12.7	382	-4.3	10.2
	Wash.& B.A.	68	-1.2	12.6	168	-4.8	11.5
	Washouts	36	-0.5	12.7	94	-3.6	11.7
Tidal Air/Body Surface: High value is favorable. Based on 2 runs of 8 minutes duration. Scored in cubic centimeters.	Good Pilots	299	371.8	121.2	304	456.7	132.7
	Successes	331	374.7	120.6	381	461.2	132.0
	Wash.& B.A.	70	364.7	109.0	173	482.5	126.4
	Washouts	38	351.7	101.5	96	482.1	124.1
Vital Capacity: High value is favorable. Score is expressed in cubic centimeters.	Good Pilots	302	5263.7	700.5	301	5189.4	677.3
	Successes	335	5258.4	700.5	365	5186.0	677.3
	Wash.& B.A.	78	5183.9	664.0	149	5134.9	700.5
	Washouts	43	4986.6	600.9	86	5109.0	707.2
Vital Capacity/Body Surface: High value is favorable. Score is expressed in cubic centimeters.	Good Pilots	297	2782.6	318.4	304	2725.8	331.2
	Successes	330	2790.3	320.0	378	2724.4	332.8
	Wash.& B.A.	76	2743.5	310.4	166	2686.2	332.8
	Washouts	43	2665.8	270.4	92	2660.6	323.2
Schneider Index: High score is favorable. Scores range from +16 to -11. Scores below +7 are considered abnormal.	Good Pilots	303	9.6	3.8	Test was not given in Part II.		
	Successes	335	9.6	3.7			
	Wash.& B.A.	69	9.7	3.2			
	Washouts	37	9.4	3.4			
Tilt Table Test:							
Syst. Blood Pressure (reclining): Score is mean of 5 readings. Taken in horizontal position before subject is tilted.	Good Pilots	302	115.3	8.8	132	115.0	9.0
	Successes	336	115.1	8.0	208	114.5	8.5
	Wash.& B.A.	70	115.4	7.4	154	114.2	8.0
	Washouts	37	117.8	6.3	88	114.8	8.5
Diast. Blood Pressure (reclining): Score is mean of 5 readings. Taken in horizontal position before being tilted.	Good Pilots	302	70.7	7.9	132	67.3	6.3
	Successes	334	70.3	7.8	202	67.1	6.4
	Wash.& B.A.	66	69.7	6.7	156	67.5	6.9
	Washouts	37	71.7	7.0	86	68.0	6.9
Pulse Rate (reclining): Score is mean of 5 readings. Taken in horizontal position before subject is tilted.	Good Pilots	302	63.2	8.2	136	63.2	11.4
	Successes	335	66.2	8.1	208	62.1	11.1
	Wash.& B.A.	70	63.1	7.9	156	62.7	10.0
	Washouts	37	66.7	8.2	86	65.0	9.4

TABLE 4 (continued)

Tests and Interpretations	Groups	Part I (classes 147-151) N	Mean	Sigma	Part II (classes 152-165) N	Mean	Sigma
Pulse Pressure Change: Minus value means pulse is greater after tilting than before.	Good Pilots	293	30.1	10.3	157	25.7	9.7
	Successes	326	30.4	10.3	218	25.6	9.4
	Wash.& B.A.	68	29.1	11.1	172	25.4	9.2
	Washouts	35	28.2	11.2	91	25.4	9.3
Pulse Rate Change: Score is diff. between highest P.R. during tilt-up interval and ave. of 5 readings before tilt.	Good Pilots	293	38.2	10.1	154	30.5	9.6
	Successes	326	37.9	10.0	216	30.1	9.2
	Wash.& B.A.	68	36.7	9.6	172	28.6	9.3
	Washouts	35	38.2	10.0	90	27.9	9.2
Smallest Pulse Pressure: Smallest difference between systolic and diastolic B.P. during tilt-up interval.	Good Pilots	293	17.3	8.0	133	23.0	8.7
	Successes	326	17.2	7.9	216	23.0	8.4
	Wash.& B.A.	68	19.2	8.5	172	22.9	7.9
	Washouts	35	21.1	9.2	89	22.8	7.8
Time to smallest Pulse Pressure: Score is time between beginning of tilt and point at which smallest P.P. occurred.	Good Pilots	293	12.2	5.8	147	8.8	5.6
	Successes	326	12.2	5.9	233	8.7	5.5
	Wash.& B.A.	68	13.0	6.2	179	8.6	5.5
	Washouts	35	13.4	6.0	93	8.3	5.4
Startle Pattern:							
Ave. Control Rate Before Startle: Score is average rate for 6 seconds before startle.	Good Pilots	368	62.4	10.6			
	Successes	412	62.3	10.6			
	Wash.& B.A.	103	62.0	9.7			
	Washouts	59	62.6	9.0			
Rate 0-6 Sec. After Startle: Score is average rate for 6 seconds after startle.	Good Pilots	365	68.8	11.6			
	Successes	409	68.5	11.5			
	Wash.& B.A.	103	68.3	11.5			
	Washouts	59	69.8	11.8			
Rate 6-12 Sec. After Startle: Score is average rate for 6-12 seconds after startle.	Good Pilots	362	64.1	11.5			
	Successes	406	64.1	11.4			
	Wash.& B.A.	103	64.4	10.3			
	Washouts	59	64.5	9.8			
Rate 12-18 Sec. After Startle: Score is average rate for 12-18 seconds after startle.	Good Pilots	357	62.9	10.9			
	Successes	400	62.9	10.9			
	Wash.& B.A.	101	62.7	10.3			
	Washouts	58	62.7	9.4			
Somatic Tremor After Startle:							
Total Duration: Score is expressed in seconds.	Good Pilots	370	1.6	2.0			
	Successes	413	1.5	2.0			
	Wash.& B.A.	102	1.6	1.9			
	Washouts	59	1.8	2.4			

Startle Pattern for Part I includes classes 147-154.

TABLE 6 (continued)

Tests and Interpretations	Groups	Part I (classes 147-151) N	Mean	Sigma	Part II (classes 152-165) N	Mean	Sigma
Initial Amplitude: Score is expressed in millimeters.	Good Pilots	370	5.4	5.1			
	Successes	413	5.4	6.0			
	Wash.& B.A.	101	5.1	4.9			
	Washouts	58	5.0	6.1			
Amplitude 3/5 Seconds After Startle: Score is expressed in millimeters.	Good Pilots	370	1.4	2.0			
	Successes	416	1.4	1.9			
	Wash.& B.A.	101	1.3	1.2			
	Washouts	56	1.3	1.2			
Alteration in T-Waves:							
Time of onset: Score is expressed in seconds.	Good Pilots	370	1.4	2.0	Startle Pattern for Part I includes classes 147-154.		
	Successes	418	1.4	1.6			
	Wash.& B.A.	102	1.5	2.1			
	Washouts	59	1.7	2.6			
Maximum Change in Amplitude: Score is expressed in millimeters.	Good Pilots	370	+0.3	0.4			
	Successes	413	+0.3	0.4			
	Wash.& B.A.	102	+0.4	0.5			
	Washouts	59	+0.4	0.6			
Persistence of T-Wave Changes: Score is expressed in seconds.	Good Pilots	370	4.2	7.9			
	Successes	413	4.1	8.0			
	Wash.& B.A.	102	4.4	8.5			
	Washouts	59	5.0	9.8			
Cold Pressor Test:							
Greatest Systolic Change: Diff. between sys. B.P. before immersing in ice water and highest B.P. after 60 sec. immersion.	Good Pilots	326	18.2	10.4	Test was not given in Part II.		
	Successes	335	18.4	10.5			
	Wash.& B.A.	39	22.4	12.2			
	Washouts	29	21.6	10.0			
Greatest Diastolic Change: Diff. between diast. B.P. before immersing in ice water and highest B.P. after 60 sec. immersion.	Good Pilots	320	22.8	11.6	Test was not given in Part II.		
	Successes	330	23.8	12.3			
	Wash.& B.A.	40	23.2	10.9			
	Washouts	30	28.3	11.5			
Electroencephalogram:							
Alpha Index: Ave. of right and left leads. Centimeters of Alpha rythm in standard length of record.	Good Pilots	299	48.7	28.4	345	63.3	25.2
	Successes	332	49.8	28.3	411	64.1	26.4
	Wash.& B.A.	70	53.9	26.1	132	66.9	26.2
	Washouts	37	50.4	26.2	66	65.0	25.8

TABLE 4 (continued)

Tests and Interpretations	Groups	Part I (classes 147-151) N	Mean	Sigma	Part II (classes 152-166) N	Mean	Sigma
Alpha Frequency: Score is cycles per sec. Frequencies less than 7 or more than 14 are not included.	Good Pilots	290	10.02	0.95	336	9.89	0.97
	Successes	322	9.94	0.93	400	9.90	0.96
	Wash.& B.A.	69	10.00	0.65	130	9.91	0.94
	Washouts	37	10.19	0.92	66	9.85	0.96
Voltage: Average amplitude of left and right leads.	Good Pilots	303	52.6	20.3	348	59.2	23.2
	Successes	336	51.6	20.3	414	59.7	18.1
	Wash.& B.A.	71	52.2	18.8	133	61.2	17.4
	Washouts	38	51.0	17.4	67	60.4	16.7
Abnormalities: Score is a rating of presence of abnormal EEG rhythms.	Good Pilots	280	0.39	0.64	247	0.76	0.93
	Successes	305	0.39	0.66	312	0.71	0.91
	Wash.& B.A.	61	0.57	0.90	130	0.53	0.82
	Washouts	36	0.64	0.98	65	0.52	0.84
Body Build (Somatotyping):							
Endomorphy: Sum of 1st component of closest approximation plus 1st component of the more distant approximation.	Good Pilots	296	3.2	2.0	157	3.1	1.7
	Successes	328	3.2	1.9	180	3.2	1.8
	Wash.& B.A.	68	3.7	1.8	49	3.8	1.7
	Washouts	33	3.9	1.9	23	3.6	1.4
Mesomorphy: Sum of 2nd component of closest approximation plus 2nd component of more distant approximation.	Good Pilots	296	8.6	1.7	157	9.0	1.5
	Successes	328	8.7	1.7	180	9.0	1.5
	Wash.& B.A.	68	8.7	1.6	49	9.1	1.7
	Washouts	36	8.8	1.6	26	9.1	1.5
Ectomorphy: Sum of 3rd component of closest approximation plus 3rd component of more distant approximation.	Good Pilots	296	6.6	2.2	157	6.3	2.0
	Successes	328	6.6	2.1	180	6.2	2.0
	Wash.& B.A.	68	6.2	1.6	49	6.6	2.1
	Washouts	36	6.0	1.8	26	6.7	2.0
Dysplasia: Differences among the somatotype designations of the five regions of the body.	Good Pilots	187	15.0	6.2			
	Successes	212	15.0	6.1	Test was not scored in Part II.		
	Wash.& B.A.	44	15.3	5.7			
	Washouts	19	16.4	5.8			

D.P.L.

PSYCHOLOGICAL TESTS

CRITICAL RATIOS OF THE DIFFERENCE OF THE MEANS AND THE P-VALUES OF THE CHI-SQUARE TEST FOR THE TWO DISTRIBUTIONS FOR SUCCESSES VS. WASHOUTS*

Test	Part I (classes 147-151) Number Succ.	Wash.	C.R.m	Chi^2 P-Value	Part II (classes 152-165) Number Succ.	Wash.	C.R.m	Chi^2 P-Value
Mental Ability (Otis)	305	35	+3.02	.05	349	101	+2.34	<.01
Mechanical Aptitude (Minnesota)	309	35	+1.87	.29	321	101	+1.91	.35
Athletic Achievement (Thorndike-Kelley)	316	37	+2.19	.07	Test was not given in Part II.			
Eye-Hand Coordination	326	37	+2.96	.05	114	73	+3.22	<.01
Two-Hand Coordination	327	35	+5.46	<.01	321	89	+3.21	<.01
Washburn Serial Action Test	326	39	+4.47	<.01	369	77	+3.27	.02
Dotting (McDougall)	333	37	-1.62	.67	436	92	+1.32	.24
Continuous Reaction (Cattell):								
Part A	309	32	+2.63	.08	Tests were			
Part B	305	32	+2.53	.07	not scored			
Parts A and B	302	30	+2.43	.13	in Part II.			
Ataxiameter (Miles)	327	36	-0.37	.38	416	108	0.58	.44
Aniseikonia:								
Ekonometer	245	32	+0.07	.49	Tests were			
Leaf Room	252	32	+1.33	.50	not given			
Frontal Plane Apparatus	97	14	-0.68	.82	in Part II.			
Ophthalmograph (fixations per line)	316	32	-0.70	.86	Test was not given in Part II.			
Dark Adaptation (Wald)	Test was not given in Part I.				143	91	+1.68	.47
Perception of Change in Position	337	37	-0.01	.55	423	106	-1.77	.28

*Successes (Succ.) = all pilots exclusive of Washouts but including Board Appearances.
Washouts (Wash.) = all pilots eliminated for poor aptitude.

Note: A positive critical ratio denotes that the successes have a performance superior to that of the Washouts.

TABLE 6

PSYCHOLOGICAL TESTS

CRITICAL RATIOS OF THE DIFFERENCE OF THE MEANS AND THE P-VALUE OF THE CHI-SQUARE TEST FOR THE TWO DISTRIBUTIONS FOR GOOD PILOTS VS. WASHOUTS PLUS BOARD APPEARANCES*

	Part I (classes 147-151)				Part II (classes 152-165)			
	Number			Chi^2	Number			Chi^2
Test	G.P.	W.&B.A.	C.R.m	P-Value	G.P.	W.&B.A.	C.R.m	P-Value
Mental Ability (Otis)	273	65	+2.05	.04	264	186	+2.82	.09
Mechanical Aptitude (Minnesota)	276	63	+2.36	.02	237	185	+1.47	.73
Athletic Achievement (Thorndike-Kelley)	293	62	+1.75	.17	Test was not given in Part II.			
Eye-Hand Coordination	303	70	+2.27	.07	97	88	+2.79	<.01
Two-Hand Coordination	303	73	+3.48	<.01	270	140	+2.89	.04
Washburn Serial Action Test	307	72	+5.34	<.01	323	120	+4.25	<.01
Dotting (McDougall)	300	70	+2.21	.25	350	174	+0.61	.23
Continuous Reaction (Cattell):								
Part A	278	62	+3.25	<.01	Tests were not scored in Part II.			
Part B	278	62	+2.37	.04				
Parts A and B	272	60	+3.38	.06				
Ataxiometer (Miles)	304	68	+0.96	.77	329	190	+1.21	.34
Aniseikonia:								
Eikonometer	218	60	+0.29	.84	Tests were not given in Part II.			
Leaf Room	292	68	+1.14	.09				
Frontal Plane Apparatus	81	30	+0.92	.12				
Ophthalmograph (fixations per line)	239	61	-0.44	.41	Test was not given in Part II.			
Dark Adaptation (Wald)	Test was not given in Part I.				65	169	+0.30	.99
Perception of Change in Position	304	70	+0.60	.18	335	194	-2.66	.06

*Good Pilots (G.P.): all pilots exclusive of Washouts and Board Appearances.
Washouts plus Board Appearances (W.&B.A.): all pilots who had difficulties in flight training and appeared before the Commandant's Advisory Board, plus all pilots eliminated for poor aptitude.

Note: A positive critical ratio denotes that good pilots have a performance superior to that of the Washouts and the Board Appearances.

TABLE 7

PHYSIOLOGICAL TESTS

CRITICAL RATIOS OF THE DIFFERENCE OF THE MEANS AND THE P-VALUE OF THE CHI-SQUARE TEST FOR THE TWO DISTRIBUTIONS FOR SUCCESSES VS. WASHOUTS*

Test	Part I (classes 147-151) Number Succ.	Wash.	C.R.m	Chi^2 P-Value	Part II (classes 152-155) Number Succ.	Wash.	C.R.m	Chi^2 P-Value
Basal Metabolic Rate	328	36	0.43	.75	382	94	0.38	.80
Tidal Air/Body Surface	331	38	1.30	.21	381	96	1.45	.35
Vital Capacity	335	43	2.75	.08	365	86	0.91	.33
Vital Capacity/Body Surface	330	43	2.79	.08	378	92	1.69	.54
Schneider Index	335	37	0.30	.95	Test was not given in Part II.			
Tilt Table:								
Systolic B.P. (reclining)	355	37	2.69	.26	203	88	0.33	.94
Diastolic B.P. (reclining)	354	37	1.11	.75	202	86	0.99	.31
Pulse Rate (reclining)	335	37	0.33	.81	205	86	3.26	.04
Pulse Pressure Change	326	35	1.10	.50	218	91	0.23	.64
Pulse Rate Change	326	35	0.19	.96	216	90	1.89	.25
Smallest Pulse Pressure	326	35	2.38	.24	215	89	0.13	.62
Time to Smallest Pulse Pres.	326	35	1.07	.08	233	93	0.50	.07
Startle Pattern:								
Rate After Startle:								
Control Rate	412	59	0.23	.81				
0-5 sec. after	409	59	0.77	.72				
6-12 sec. after	406	59	0.30	.28				
12-18 sec. after	400	58	0.17	.86				
Somatic Tremor:								
Total Duration	413	59	0.70	.49	Startle Pattern for Part I			
Initial Amplitude	413	56	0.35	.76	includes classes 147-154.			
Amplitude 3/5 sec. after st.	415	56	0.15	.39				
Alterations in T-Waves:								
Time of Onset	413	59	0.91	.45				
Max. Change in Amplitude	413	59	0.98	.75				
Persistence of T-Wave	413	59	0.70	.49				
Cold Pressor:								
Greatest Systolic Change	335	20	1.68	.16	Test was not given in Part II.			
Greatest Diastolic Change	330	30	2.26	.80				
Electroencephalogram:								
Alpha Index	332	37	0.18	.71	411	86	0.34	.64
Alpha Frequency	322	37	1.56	.33	400	86	0.54	.29
Voltage	338	38	0.17	.98	414	87	0.32	.28
Abnormalities	305	36	1.56	.05	312	85	1.73	.17
Body Build (Somatotype):								
Endomorphy	328	36	2.19	.43	180	26	1.35	.29
Mesomorphy	328	36	0.45	.30	180	26	0.52	.54
Ectomorphy	328	36	2.07	.60	180	26	1.19	.18
Dysplasia	212	10	0.31	.92	Test was not scored in Part II.			

*Successes = all pilots exclusive of Washouts but including Board Appearances.
Washouts = all pilots eliminated for poor aptitude.

TABLE 8

PHYSIOLOGICAL TESTS

CRITICAL RATIOS OF THE DIFFERENCE OF THE MEANS AND THE P-VALUE OF THE CHI-SQUARE TEST FOR THE TWO DISTRIBUTIONS FOR GOOD PILOTS VS. WASHOUTS PLUS BOARD APPEARANCES*

Test	Part I (classes 147-161) Number G.P.	W.&B.A.	C.R.m	Chi^2 P-Value	Part II (classes 152-166) Number G.P.	W.&B.A.	C.R.m	Chi^2 P-Value
Basal Metabolic Rate	296	68	1.13	.40	308	168	0.87	.87
Tidal Air/Body Surface	299	70	0.48	.04	304	172	2.20	.05
Vital Capacity	302	78	1.45	.68	301	149	0.78	.71
Vital Capacity/Body Surface	297	76	0.82	.28	304	166	1.24	.55
Schneider Index	303	69	0.25	.16	Test was not given in Part II.			
Tilt Table:								
Systolic B.P. (reclining)	302	70	0.09	.75	132	154	0.73	.94
Diastolic B.P. (reclining)	302	69	1.04	.12	132	156	0.31	.46
Pulse Rate (reclining)	302	70	0.09	.62	136	156	0.40	.87
Pulse Pressure Change	293	68	0.70	.58	137	172	0.25	.84
Pulse Rate Change	293	68	1.11	.71	134	172	1.73	.06
Smallest Pulse Pressure	293	68	1.70	.34	133	172	0.20	.78
Time to Smallest Pulse Pres.	293	68	1.02	.18	147	179	0.29	.44
Startle Pattern:								
Rate After Startle:								
Control Rate	368	103	0.14	.93				
0-6 sec. after	386	103	0.41	.87				
6-12 sec. after	362	103	0.39	.89				
12-18 sec. after	357	101	0.25	.95				
Somatic Tremor:					Startle Pattern for Part I includes classes 147-154.			
Total Duration	370	102	0.00	.73				
Initial Amplitude	370	101	0.64	.63				
Amplitude 3/5 sec. after st.	370	101	0.30	.72				
Alterations in T-Waves:								
Time of Onset	370	102	0.36	.88				
Max. Change in Amplitude	370	102	1.00	.61				
Persistence of T-Waves	370	102	0.87	.75				
Cold Pressor:								
Greatest Systolic Change	325	89	2.00	.11	Test was not given in Part II.			
Greatest Diastolic Change	320	90	1.50	.41				
Electroencephalogram:								
Alpha Index	299	70	1.17	.43	345	132	1.00	.62
Alpha Frequency	290	69	0.17	.33	336	130	0.22	.99
Voltage	303	71	2.35	.96	348	133	1.04	.56
Abnormalities	280	61	1.36	.15	247	130	2.56	.05
Body Build (Sometotype):								
Endomorphy	296	68	2.08	.32	157	49	2.61	.00
Mesomorphy	296	68	0.45	.48	157	49	0.58	.67
Ectomorphy	296	68	0.32	.01	157	49	2.32	.03
Dysplasia	187	44	0.31	.71	Test was not scored in Part II.			

*Good Pilots = all pilots exclusive of Washouts and Board Appearances.
Board Appearances = all pilots who had difficulties in flight training and appeared before the Commandant's Advisory Board.
Washouts = all pilots eliminated for poor aptitude.

TABLE 7

P-VALUE OF CHI-SQUARE FOR BOTH THE PSYCHOLOGICAL AND PHYSIOLOGICAL TESTS
(The data show a comparison of results obtained
with and without washouts in parent population)

	Part I		Part II	
	Successes vs. Washouts	Washouts vs. Parent Distribution	Successes vs. Washouts	Washouts vs. Parent Distribution
I. Psychological Tests:				
Mental Ability (Otis)	.05	.03	<.01	<.01
Minnesota Paper Form Board	.29	.44	.35	.05
Thorndike-Kelley Athl. Achiev.	.07	.20	Test was not given in Part II.	
Eye-Hand Coordination	.05	.17	<.01	.04
Two-Hand Coordination	<.01	.04	<.01	<.01
Washburn Serial Action Test	<.01	<.01	.02	.03
Dotting (McDougall)	.57	.69	.24	.22
Continuous Reaction (Cattell):				
Part A	.08	.47	Test was not	
Part B	.07	.42	scored in	
Parts A and B	.13	.31	Part II.	
Ataxiameter (Miles)	.85	.80	.44	.68
Ophthalmograph (fixations/line)	.80	.33	Test was not given in Part II.	
Percep. of Change in Position	.55	.81	.28	.72
II. Physiological Tests:				
Basal Metabolic Rate	.75	.83	.80	.26
Tidal Air/Body Surface	.21	.91	.35	.80
Vital Capacity	.06	.39	.83	.28
Vital Capacity/Body Surface	.05	.08	.64	*
Schneider Index of Neurocirculatory Fitness	.95	.80	Test was not given in Part II.	
Tilt Table:				
Pulse Pressure Change	.30	.63	.64	*
Pulse Rate Change	.98	.78	.23	*
Smallest Pulse Pressure	.24	.25	.62	*
Time to Smallest Pulse Pres.	.08	.06	.07	.48
Electroencephalogram:				
Alpha Index	.71	.85	.84	*
Alpha Frequency	.33	.88	.29	*
Voltage	.98	.93	.28	*
Abnormalities	.05	.30	.17	*
Somatotype:				
Endomorphy	.45	.73	.29	*
Mesomorphy	.80	.23	.54	*
Ectomorphy	.60	.76	.18	*
Dysplasia	.92	.80	Test was not scored in Part II	

*Not computed for those tests in Part II.

group and the others in Part II.[37]

As a group the physiological tests did not distinguish the washouts from the successful pilots as well as the psychological tests.[38] (See Tables 7 and 8.) None of the comparisons obtained critical ratios of 3.0 or over, although in Part I the tests for Vital Capacity, Systolic Blood Pressure (reclining) gave critical ratios of 2.5 or above when the significance of the means was tested, (see Table 7). The results, however, were not verified in Part II, and the P-values were too high throughout to credit the assumption that these tests, as given, distinguish washouts from successes. It is known, however, that there is wide variation in these tests for any one individual. The measures used are accurate for the time of measurement (i.e., are accurate measures of biological instants), but cannot be considered as truly characteristic of the functions measured over a long period of time. It is possible that better selective results might have been obtained with the physiological tests if the reliability of these measures had been improved by repeating the tests on each subject.

Table 9, which compares the P-values obtained from the comparison of Successes vs. Washouts and Washouts vs. the Total Population, shows that the four tests selected on the basis of the two-by-n chis and the comparison of means (see Table 5) are also the ones which show low P-values when the chi calculation is made by comparison of washouts and the parent population. The two methods of calculating chi-square require slightly different interpretations. A P-value of 0.01 in comparison with parent population has the very simple and direct meaning that a random selection of the same number of pilots as are contained in the washout selection would by chance differ from the parent population to this extent only once out of 100 times. The same P-value representing the other type of chi-square (Successes vs. Washouts) indicates that two independent samples of these sizes would differ as much as do the two being studied only once out of 100 times by chance.

This technique of comparing the washout group with its parent distribution was chosen as a method for preparing the way for a multiple use of chi. Only those tests were selected which truly distinguished the washout group from its parent universe.

Application of a Multiple Chi Technique.[39] Further analysis of the data has been made in an attempt to select the best battery of tests from the to-

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37The Continuous Reaction Test (Cattell) shows high critical ratios and low P-values, but this difference is not true of washouts alone and cannot be validated by the results in the Part II sample.

38It should be noted that the rigorous physical examination given at the time of selection of the applicants might account, in part, for the negative results shown by the physiological measures used in this study.

39Franzen, Raymond A method for selecting combinations of tests and determining their best "cut-off" points to yield a dichotomy most like a categorical criterion. Washington, D. C.: C.A.A. Division of Research, Report No. 12, March 1943.

TABLE IV

INTERCORRELATIONS OF THE PSYCHOLOGICAL TESTS
(r and eta)

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) Eye-Hand Coordination	r	---								
	eta									
(2) Otis Test of Mental Ability	r	141	---							
	eta	224								
(3) Ataxiameter	r	171	-010	---						
	eta	251	165							
(4) Two-Hand Coordination	r	235	246	045	---					
	eta	270	358	136						
(5) Perception of Change in Position	r	053	130	156	041	---				
	eta	201	180	328	123					
(6) Washburn Serial Action	r	208	290	135	297	013	---			
	eta	282	297	294	343	194				
(7) Batting	r	205	054	077	170	-090	276	---		
	eta	245	236	196	263	260	283			
(8) Minnesota Paper Form Board	r	108	360	068	225	-006	253	182	---	
	eta	204	336	145	274	197	332	289		
(9) Thorndike-Kelley Athl. Achiev.	r	005	127	039	156	127	045	-118	-005	---
	eta	157	217	144	233	277	207	171	203	
N		373	356	371	371	373	374	371	339	
Mean		70	52.2	449	59.3	25.1	5.97	215	45.1	
Sigma		6.7	6.7	113.7	11.9	9.4	1.03	25.2	8.4	

Note: The decimal points have been omitted in presenting the correlations.

tal used. A brief outline of the various procedures used and a summary presentation of the results obtained are given here. Only a few of the more essential points will be discussed, the details being presented in separate reports on file with the Committee on Selection and Training of Aircraft Pilots of the National Research Council.[40] The procedures used were as follows:

1. Correlation of each of nine psychological tests with every other, computing both r's and etas.

2. Determination of the significance of the differences between the distribution of scores of selected groups of pilots and the distribution of scores of the parent population (using chi-square). The selected groups used were: (a) washouts because of poor aptitude, (b) pilots who had board appearances but were not washed out, (c) washouts for reasons other than aptitude.

3. An analysis of those tests which differentiated these groups in order to determine efficient "cut-off" points (by use of chi) for eliminating washouts. This included a determination of the reliability of the chi obtained from various cut-off points, using random halves of the material.

4. Consideration of combinations of the selected tests to determine a pattern of cut-off points with greater efficiency than that provided by any one test alone (multiple chi).

Inspection of data in Table 10 shows that both linear and curvilinear relations among the tests are low. The highest relationship is that between the Otis and Minnesota Paper Form Board Tests with an r of 0.36 and an eta of 0.39. The Washburn Serial Action Test scores correlate most highly with the scores on the other tests, the etas in this case being close to 0.3 with every other test, except Perception of Change in Position and the Athletic Achievement Test, and these were found to have doubtful sampling consistency.

Results obtained for the P-value of chi-square have been summarized in Table 9, where they are listed in comparison. Using as the level of significance 0.01 for the P-value from the two-by-n analysis and 0.05 for the P-value from the other chi-square, it is seen that the Otis Test of Mental Ability, the Two-Hand Coordination Test, and the Washburn Serial Action Test consistently provided the best differentiation between washouts and successes.

40Franzen, R. and McFarland, R. A. Statistical analysis of data obtained in the Pensacola study of naval aviators Parts I and II. (In two volumes.) Franzen, R., McFarland, R. A., and Graybiel, A. Statistical analysis of the tilt table test of cardiovascular efficiency in the Pensacola study of naval aviators; Franzen, R. and McFarland, R. A. Statistical analysis of the electroencephalogram and somatotype measures in the Pensacola study of naval aviators. Final reports to the Committee on Selection and Training of Aircraft Pilots, 1942.

The next problem considered was the specific one of applying a battery of the tests to an efficient elimination of the cadets most likely to fail in flight training. The assumption made was that it was not necessary to identify degrees of skill throughout the whole range of flying efficiency, but rather, to differentiate between two groups of cadets, i.e., a group which passed flight training at Pensacola and another group which failed. The multiple chi technique was used for this purpose. By this technique, several points were located in the distribution of the scores of the Otis Test of Mental Ability, the Two-Hand Coordination Test, and the Mashburn Serial Action Test below all three of which it was probable that a larger proportion of potential washouts than potentially successful pilots would fail. The following objective was used as a basis for determining the failure points on the tests: to eliminate a maximum number of washouts and a minimum number of those who would pass their flight training course. After applying this technique to the separate parts, it was found that Parts I and II could be combined because the patterns of failure in the Otis Test of Mental Ability, the Two-Hand Coordination Test, and the Mashburn Serial Action Test, in combination, showed surprising consistency or similarity. Various rejection levels were obtained and are shown in Table 11.

In all but one of the pairs of percentages the washout proportion is between two and three times as large as the proportion of non-washouts. The combinations of Two-Hand and Mashburn Tests and Otis and Two-Hand Tests, with failure set at -0.1 sigma, will eliminate half the washouts and one-fourth of the remaining cadets. If such a proportion of unnecessary rejections is too extravagant, the Otis, Two-Hand, and Mashburn Tests, with

TABLE 11

CHI FOR FAILURE ON COMBINATIONS OF TESTS
(Parts I and II combined)

Failure on Tests	Chi	Percentage Failed: Washouts	Percentage Failed: Remaining Cadets
Two-Hand and Mashburn	5.17*	53	25
Otis and Two-Hand	5.05*	49	26
Otis, Two-Hand, and Mashburn	4.70*	36	14
Otis and Mashburn	4.43*	46	22
Two-Hand and Mashburn	5.75#	38	13
Otis, Two-Hand, and Mashburn	5.33#	25	6
Otis and Mashburn	4.68#	32	12
Otis and Two-Hand	4.44#	37	16
Otis, Two-Hand, and Mashburn	4.61ø	32	12
Otis and Two-Hand	4.23ø	43	21
Otis and Mashburn	4.12ø	40	19

*Failure level = -.1 sigma on all 3 tests.
#Failure level = -.4 sigma on all 3 tests.
øFailure level = -.1 sigma on Two-Hand and Mashburn and -.4 on Otis

failures at -0.4 sigma, will eliminate 25% of the potential washouts and only 6% of the potential pilots. The Otis and Mashburn Tests in combination operate best when -0.1 sigma is the cut-off for the Mashburn and -0.4 sigma for the Otis. Then the rejected group includes two-fifths of the washouts and only one-fifth of the desirable candidates.

When either two or three of the above tests are used together in determining a cut-off point for eliminating candidates, the proportions thus eliminated are efficient and economical, being about one-half of the potential washouts and not more than one-fourth of those who would be able to pass the course. An important advantage of this form of analysis is to show the degree of compensation that exists among the various tests. From the P-values previously presented for the separate tests, it is apparent that all of the tests mentioned above are related to the probability of being washed out. But they do not indicate whether failure in mental ability is compensated for by success in psychomotor tests, or vice versa. If the analysis described above is used, it is obvious that compensation does exist; for example, being low in psychomotor ability but high in average intelligence does not predict rejection nearly as well as being low in both traits. Likewise, being low in intelligence but high in psychomotor ability does not predict failure as well as being low in both. Thus, it is possible to show that compensation exists between two or more tests if the criterion of failure on all tests eliminates a larger number of washouts and a smaller number of those who should complete their course than does the criterion of failure on one test or the second or the third, etc.[41]

DISCUSSION OF RESULTS OBTAINED FOR EACH TEST

In the following paragraphs, a brief statement will be given of the findings obtained for each test with special reference to the following factors: (1) the extent to which the test differentiated the good pilots from the washouts, based upon the critical ratios of the difference of the means and on the P-values of the chi-square test between the two distributions; (2) steps taken to improve the apparatus and procedures for administration of the tests; and (3) special considerations in the use of certain of the physiological tests. The distribution tables for each test and various classifications of good and poor pilots, too extensive to include here, are available in a separate report on file with the Committee on Selection and Training of Aircraft Pilots of the National Research Council. A number of these distributions are presented in Appendix E of this report.

The Psychological Tests

I. Personal and Medical History Questionnaire

Personal and Medical History Questionnaire. The results from the questionnaire relating to the family background, personal and medical history,

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41 Editor's Note. The elimination of only those who fail to pass a cutting score on both of the two tests (or all of n tests) is the obverse of the practice of eliminating those who fail to pass a cutting score on any one of the tests in the battery. A further discussion of this concept of compensation and of the principles underlying the applicability of the multiple chi technique in evaluating the compensatory relationships among tests is found in: Franzen, Raymond. Op. cit.

environmental influence, education, and vocational and aeronautical interests have been tabulated in terms of the number and percentage of those answering each question. This information for Successes and Washouts is given in Tables A-1 through A-5 in Appendix A. The results are too extensive to comment on in detail. Information in regard to any of the specific items may be obtained from the summaries in the tables. An attempt was made to determine which questions in the various items of the questionnaire showed a significant difference in characterizing the successes and washouts. The criterion for significance was the difference in percentage divided by the sigma of this difference. Results are tabulated in Table A-6 of Appendix A where items are shown in which the critical ratios were 2.0 or above.

II. Paper and Pencil Tests

Mental Ability (Otis Higher Examination). The results obtained with this test were rather promising. It differentiated the successful pilots from the washouts better than the other paper-and-pencil tests, (see Tables 5 and 6). It is recognized, however, that any general test of intelligence or mental ability might serve equally well. Presumably the test is of greatest value in eliminating those students whose mental ability is so poor as to handicap them in the acquisition and retention of the information necessary to master the facts which must be known and retained in learning to fly.

Mechanical Aptitude (Minnesota Paper Form Board). This test was used in the battery because successful flying appears to require some interest in and ability to deal with mechanical things. It did not differentiate the successful pilots from the washouts as well as the Otis Test. A limitation of this test is that it involves primarily only one aspect of mechanical aptitude, namely, perception of form relations.

Athletic Achievement (Thorndike-Kelley). This test was developed during the last war by Drs. E. L. Thorndike and Truman Kelley to determine the extent to which athletic skills are related to success in flying. The test proved to be a poor one in differentiating the successful pilots from the washouts in this study. This may have been due to the fact that the questions are too generalized to differentiate the athlete of superior skills from one of ordinary ability. Also, the test is not devised so as to single out those individuals who excel in sports in which judgment of speed and distance and motor coordination are especially important, as in golf, fencing, skiing, and tennis.[42]

III. Psychomotor Tests

Eye-Hand Coordination Tests. This test appeared to distinguish the successful pilots from the washouts in that the critical ratios were 2.96 and 3.22 for Parts I and II, respectively, and also the P-values were less than 0.01 in Part II and 0.05 in Part I, (see Table 5). In Fig. 20A, the amount

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[42]Recent work on biographical instruments of this sort has indicated that athletic history items bear a positive association with success in flight training.

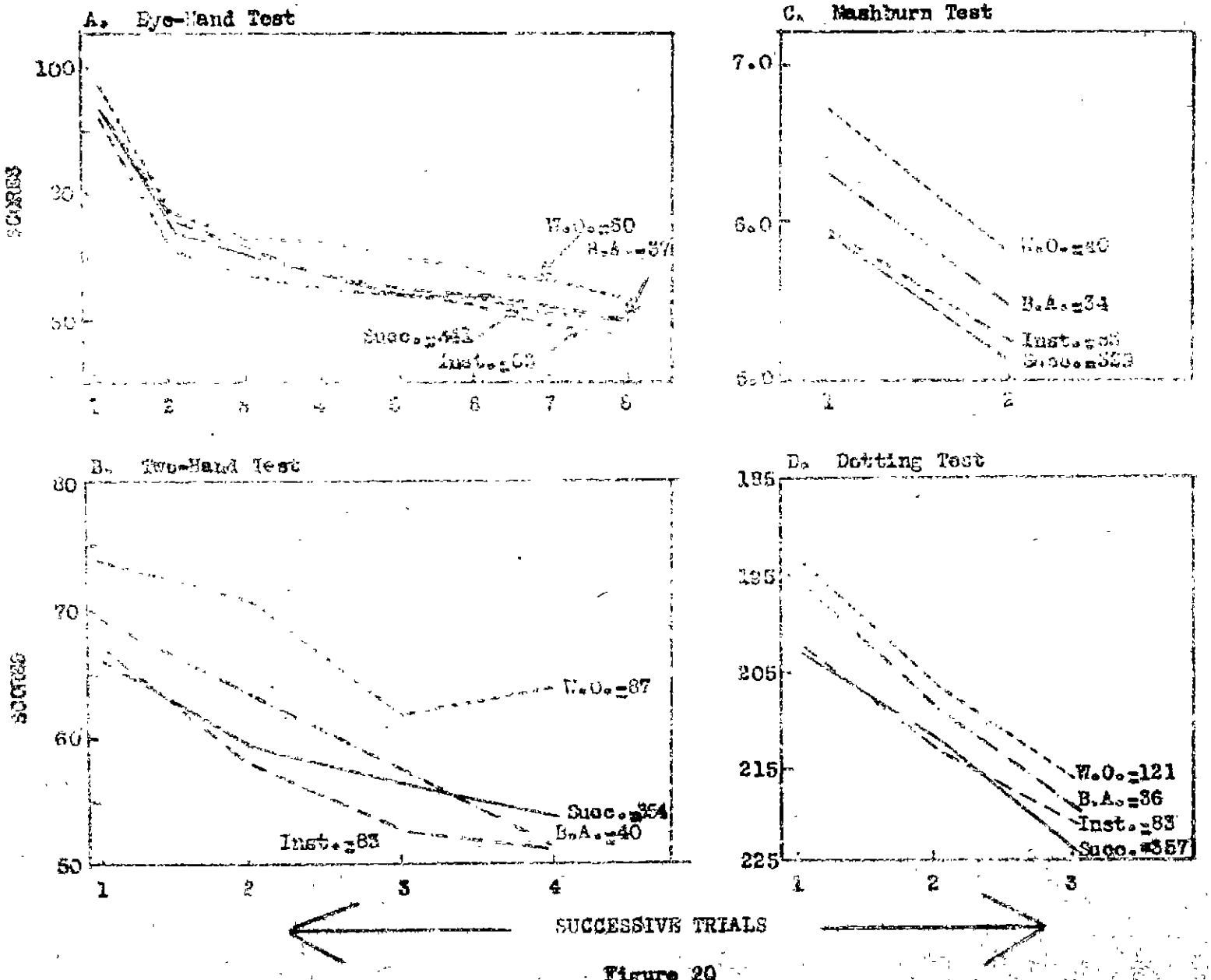

Figure 20

Improvement on Successive Trials as shown by Instructors, Successes, Board Appearances, and Washouts on Four Pa e d- motor T

of improvement on eight successive trials has been plotted for the instructors, successes, board appearances, and washouts. It is interesting to note that the instructors and successes were on the average better throughout the learning curve, and the washouts were poorer.

Two-Hand Coordination Test. This psychomotor test also differentiated the successful pilots from the poor ones, as judged by the high critical ratios and reliable P-values for the two distributions. In fact, this test gave consistent results throughout, in spite of the fact that the initial apparatus used at Pensacola had certain defects. For instance, the amount of deviation in the control of the targets - i.e., the scoring system - was based on a system of pulleys which tended to slip; also, a phonograph motor was used to drive the apparatus and unless it was carefully rewound at the beginning of each trial, the timing differed slightly.

In Figure 20B, the four successive trials have been plotted in the form of learning curves for the four groups of subjects as indicated. The fact that the successes made significantly better scores throughout than the washouts is indicated by the large difference between the two learning curves. The washouts were much poorer; in fact, as a group they showed a poorer average response on the fourth trial than on the third.

Washburn Serial Action Test. This test proved to be of value in differentiating the good pilots from the poor ones. The critical ratios (means) were, with one exception, 4.0 or above in the various groups shown in Tables 5 and 6. Also, the P-value is low in both groupings.[43]

In the administration of this test, each cadet was given two trials of 40 settings each. The amount of improvement on these successive trials is shown graphically in Figure 20C for the various classifications of pilots as to ability in flight training. The successes and instructors are significantly better in their scores than the washouts and board appearances. An examination of this figure reveals that the relative improvement of the successes and washouts is approximately the same, the chief difference in the curves being that the washouts were approximately one minute slower in their scores on both trials.

A comparison has been made between the two successive trials on the Washburn Test for the cadets in Part I (classes 147-151). These data are shown in Table 12. The means and standard deviations in Trials 1 and 2 for the different groupings of cadets with respect to success in flight training can be observed in this table. The critical ratios of the differences between the means for the groups are all 4.0 or above. The P-values are

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[43] Similar results have been obtained in other studies of student pilots where the test has been used in comparing successful pilots with washouts. A detailed report of these results, with suggested improvements in the instrument, may be found in: McFarland, R. A. and Chapanell, R. C. A revised serial reaction time apparatus for use in appraising flying aptitude. Washington, D. C.: C.A.A. Airman Development Division, Report No. 34, September 1944.

all less than 0.01, indicating a high probability of a true difference between the two distributions.[44]

TABLE 12

COMPARISON OF TWO SUCCESSIVE TRIALS ON THE MASHBURN TEST
(Part I, classes 147-151)

Trials	Group	N	Mean	Sigma	C.R.$_m$	Chi^2 P-Value
1	Successes	335	5.83 ± 0.05	0.96 ± 0.04	+4.47	<.01
	Washouts	39	6.68 ± 0.18	1.15 ± 0.13		
2	Successes	329	5.12 ± 0.04	0.78 ± 0.03	+4.00	<.01
	Washouts	40	5.80 ± 0.17	1.06 ± 0.12		
1	Good Pilots	303	5.78 ± 0.05	0.92 ± 0.04	+5.64	<.01
	Wash. & B. A.	72	6.53 ± 0.13	1.15 ± 0.10		
2	Good Pilots	295	5.08 ± 0.04	0.74 ± 0.03	+4.62	<.01
	Wash. & B. A.	73	5.68 ± 0.12	1.02 ± 0.08		

Dotting Test (McDougall). The results obtained with this apparatus were not significant in comparison with the other psychomotor tests mentioned previously; that is, the Eye-Hand, Two-Hand, the Mashburn Tests. The data for the four groupings as to success in flying are shown graphically in Figure 20D. The curves indicate an improvement in all groups, and the various groups maintain their relative position to each other, the washouts being on the average approximately ten points poorer throughout.

Continuous Reaction Test (Cattell). As judged by the critical ratios between the means in Part I, this test appeared to differentiate the successful pilots from the washouts, the critical ratio being 2.5. This value was raised to 3.3 when good pilots were compared with washouts and board appearances (see Tables 5 and 6). The P-values of the chi-square test were not significant.

Experience with the test revealed certain practical limitations, especially in regard to scoring, since the scoring system employed required considerable time. The test should be improved by rebuilding the equipment with a system of electrical contacts or some other method so that the scoring would be automatic.

Ataxiameter (Miles). The results obtained with this test, from the point of view of distinguishing successful pilots from washouts, were poor throughout the study. The critical ratios and P-values were on the average lower than for any other psychological test.

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[44]The fact that the differences were consistent for both tests is an indirect indication of satisfactory reliability of the test.

IV. Visual and Perceptual Tests

Aniseikonia (spatial localization). This study of aniseikonia in aviators was originally sponsored by Dartmouth College and the Civil Aeronautics Administration. The first experiments were carried out on civilian airline pilots in Kansas City, Missouri. Because of the difficulties in obtaining subjects, the project was moved to Pensacola through the cooperation of the Committee on Selection and Training of Aircraft Pilots of the National Research Council and of the Bureau of Aeronautics, U. S. Navy. In this way it was possible to add the three tests described on page 11 (Eikonometer, Leaf Room, and Frontal Plane Apparatus) to the series of tests being given to the group of aviation cadets participating in this study.

The results obtained with the three tests relating to the spatial sense of 245 successful pilots and 33 washouts are shown in Tables 5 and 6. None of the critical ratios between the means of the successful pilots compared with the washouts was above 1.35 and the P-values were high, indicating no significant differences between the two distributions.[45]

Photographs of Eye Movements (Ophthalmograph). As described on page 11 the test has two parts: (1) the photographing of the number of fixations while reading a printed line, and (2) the measurement of the ocular tremors and related anomalies while fixating on a target. The results relating to the first variable gave a critical ratio between the means of 0.70 in comparing the successes and washouts in Part I, and the P-value showed little difference between the two distributions. The test was not given to the cadets in Part II. The analysis of the records relating to the ocular fixations on the target revealed only a small number of abnormalities to which any significance could be attached. It was difficult to score the records numerically, and since only a small number of ocular tremors or related anomalies were found by inspection of the records, the analysis was not completed in a quantitative way.

Dark Adaptation (Night Vision). The results obtained with the Wald Adaptometer (see page 12) on 143 successful pilots and 91 washouts are shown in Tables 5 and 6. The critical ratio between the means of the successes and washouts was 1.7. This value dropped to 0.3 when the good pilots were compared with washouts plus board appearances.

Tilt Chair - Perception of Change in Position. The results indicate that this test did not distinguish the successes from the washouts. In Tables 5 and 6 tests of significance between successful and unsuccessful pilots were not indicative of differences other than chance ones.

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[45]Additional details as to test administration and an independent treatment of the aniseikonia test results, including a comparison of the naval cadets with other populations, may be found in: Incidence and effect of aniseikonia on aircraft pilotage. Washington, D. C.: C.A.A., U. S. Department of Commerce, Technical Development Report No. 30, March 1943.

The Physiological Tests

This part of the report deals with the analysis of each physiological test. Particular difficulty has been encountered in this phase of the work for the following reasons: In the first place, the physiological tests were subject to variations in the same individual from time to time. In the second place, physiological measures are more subject to environmental influences, such as variations in temperature. Thirdly, factors such as emotional stability or physical fitness may be considered by some to have a more complex basis and consequently are more difficult to measure than variables such as mental ability or psychomotor control and coordination. Finally, it should be kept in mind that certain phases of this study were introduced, not alone from the point of view of selection, but also to contribute to certain individual aspects of the flight physical examination. Illustrations of this latter point may be given in terms of the Basal Metabolism Test, Electrocardiography, and Brain Wave Tests.

I. Metabolism and Respiration Tests

Basal Metabolic Rate. The basal metabolic rates were for the most part within the normal range for male subjects of their age. If one takes the normal range as being ± 15, the proportions above and below this range may be considered abnormal. Such data for the Pensacola group are presented in Table 13. The percentage of washouts and board appearances who had basal metabolism rates -15 or lower, in both Parts I and II, is almost twice as great as the percentage of successful pilots. In no other respect did the test differentiate the successes from the washouts, as can be seen in the critical ratios and P-values in Tables 7 and 8.

TABLE 13

PERCENTAGE OF CADETS HAVING BASAL METABOLIC RATES GREATER THAN +15 OR SMALLER THAN -15

	N	Percentage over +15	Percentage under -15
Part I (classes 147-151)			
Good Pilots	296	13.3%	7.7%
Successes	328	13.0	7.8
Wash. & B. A.	69	11.8	13.3
Washouts	36	13.9	16.7
Part II (classes 152-165)			
Good Pilots	308	4.2	7.5
Successes	382	5.0	8.9
Wash. & B. A.	168	8.3	13.1
Washouts	94	8.5	11.7

Tidal Air Volume. The results of this test did not show a significant difference between the successes and failures as judged in terms of the critical ratios and P-values (see Tables 7 and 8). This is one of the two tests in the entire series that has shown a reversal in the means - i.e., where the

washouts have been slightly better, according to the hypothesis being studied, than the successes. Also, it should be noted that the mean values in Part II are larger than those of Part I. No explanation can be given for either of these two differences in the means, except for the possible influence of changes in temperature. Part I of the study was carried out in the summer and Part II in the fall and winter months.

Vital Capacity. The critical ratio between the means of the successes and washouts in Part I was 2.8 and the P-value was 0.08 (see Tables 7 and 8). The P-value for Vital Capacity / Body Surface was more reliable in differentiating the two distributions, although its value was only 0.05.

II. Physical Fitness Tests

Schneider Index of Neurocirculatory Fitness. This test did not differentiate the cadets who passed, from the washouts, and the results in both groups showed similar means and standard deviations. The index was only given to the subjects in Part I. The test was used in this study not only to evaluate differences in physical fitness between the various groups, but also to obtain the pulse rate and blood pressure of each cadet under standardized conditions.

Tilt Table - Response to Change in Position. In this test, seven different variables relating to pulse rate and blood pressure were studied in determining whether poor responses were observed more frequently in the washouts than in the successful pilots. The different variables are described in Table 4 along with the means and standard deviations for the various groups. Of these measurements the only ones which distinguish successes from washouts are the Smallest Pulse Pressure (critical ratio of 2.38 in Part I) and the Systolic Blood Pressure (critical ratio of 2.50 in Part I). These results do not hold true in comparing good pilots with washouts plus board appearances, and the differences were not so reliable in Part II as in Part I. Further analysis of these data will be given below.

Study of Centrifugal Acceleration (g). As indicated above, the purpose of this study was to correlate a pilot's susceptibility to centrifugal acceleration (i.e., "black-out") with ease of fainting, as measured on the tilt table, and with certain other physiological tests, such as the carotid sinus sensitivity, effect of putting the hand in ice water, Schneider Index, and somatotyping. Since the cadets were in the early stages of primary training, with no experience in dive bombing, it was not possible to analyze their susceptibility to the effects of centrifugal acceleration. The instructors provided an excellent group of experienced pilots, however, who had been repeatedly subjected to various maneuvers which might cause the blackout and who had also taken the physiological tests tabulated in Table 19. A number of pilots subjected themselves to blackouts in order to make observations for this study. Sixty-two of these pilots were interviewed and questioned in detail concerning their susceptibility to the effects of centrifugal acceleration and the nature of their subjective reactions under this stress. All but one of the men interviewed admitted that they had been wholly or partially blacked out in flight. The one exception claimed that he had repeatedly made very quick pull-outs, some at 10 g or more, without blacking out.

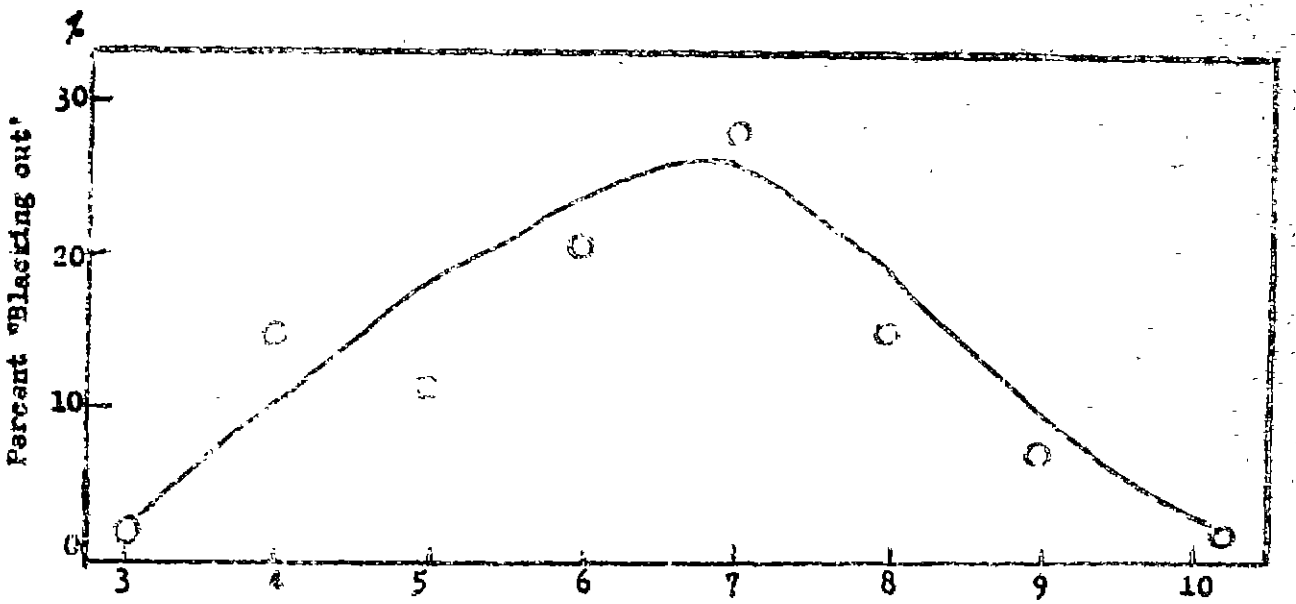

Figure 21

Percentage of Pilots (N = 62) "Blacking out" at Various Values of g

One cannot yet speak in physiological terms of one group of pilots who will black out and another who will not. It is recognized that all pilots will black out when subjected to a sufficient number of g's for a long enough time. Thus, there can be no hope of any test which might select pilots who are completely immune to the blackout. The purpose of the study, therefore, was to find a test, or series of tests, which might detect those who are less susceptible to the blackout than others. In addition to the variation of one individual from another, there are differences within each pilot from one time to another, depending upon his state of fitness. Interviews were carried out with each pilot in a systematic way by the same physician, Dr. Stanley Bennett. A standardized set of questions was asked, followed by a discussion to clarify each point.

One important aspect of the study related to the determination of how many g's each pilot could stand without blacking out. About half of the men interviewed had flown in planes with accelerometers and could state their tolerance in terms of g's based upon a number of direct observations. The others had flown with experienced pilots who knew the approximate amount of acceleration in each dive, or had evidence from indirect but fairly reliable sources. Data based upon direct accelerometer readings for each pilot in flight would have been more desirable, but such readings were not possible under the conditions of this study. It should be kept in mind that the reliability of the stated tolerance in terms of g's may be influenced by the following factors: First, it is probable that in many instances a considerable amount of impairment of cerebral function may occur without any subjective appreciation of this fact on the part of the pilot. Second, a number of the pilots had done most of

their flying in patrol bombers or other heavy aircraft and had had little experience with the high accelerations such as occur in dive bombing maneuvers. Third, only a few of them had adequately considered the duration of acceleration, which is an important factor in relation to the degree. The stated tolerance varied between 3½ and 10 g, with the mode at 6 to 6½ g. The various responses fell on a normal distribution curve as shown in Fig. 22. The data, therefore, constitute a fairly representative sample. A mean of 6½ g is also given as the average tolerance by von Diringshofen,[46] it is one or more g above the average figure given by Armstrong and Heim.[47]

An attempt was made to ascertain from the pilots how much delay there was between the time of maximum acceleration and the subjective appreciation of symptoms. Although all of the pilots agreed that there was some delay, their opinions as to its duration are unreliable because no pilot interviewed had ever attempted to time this interval accurately. Also, there is no sharp point of demarcation from which to begin timing, and the onset of symptoms is ordinarily not instantaneous but built up over an appreciable interval. Hence, no reliable conclusions can be based on the pilot's estimation of the time interval involved.

Each pilot was questioned in detail concerning the subjective experiences during and after blacking out. There was a wide variation in the content of these reports, so each one cannot be discussed in detail here. The results are presented in summary form in Table 14. Visual symptoms predominated, but it should be noted that of the 62 instructors interviewed only 32 reported visual symptoms alone. Diffuse blurring or greying effects were prominent, while concentric narrowing of the visual fields, "curtain" effects, and the appearance of colors, scotomata, and alterations in ability to focus, were less frequent. Other frequent symptoms related to impairment of hearing, feelings of confusion and disorientation, faintness, numbness, and visceral effects.

In discussing the methods of attempting to prevent the blackout, only 14 of the pilots reported that they considered the experience disagreeable or dangerous, and most of them stated that they did nothing to avoid the blackout or to increase their tolerance during a pull-out. Twenty-two pilots reported that they sometimes "yelled" or tensed their abdominal muscles to increase their tolerance, though only 11 thought that this actually increased their resistance. The remainder thought that tensing their muscles was ineffective. A number of the pilots sought to avoid blacking out by suitably maneuvering their plane rather than by tensing their muscles or otherwise seeking to increase their tolerance.

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[46] von Diringshofen, H. Bis zu welcher Stärke kann der Mensch im Flugzeug Zentrifugalkräfte vertragen und welchem Einfluss hat hierauf die Änderung der Körperhaltung. Jahrbuch des Deutschen Luftfahrtforschung. R. Olderbourg. München und Berlin. 1937, pp. 128-130.

[47] Armstrong, H. G. and Heim, J. W. The effect of acceleration on the living organism. J. Aviation Med., 1938, 9, 199-215.

TABLE 14

NUMBER OF PILOTS REPORTING SYMPTOMS ASSOCIATED WITH BLACKING OUT

		Yes	No	Uncertain	Number Reporting
I.	Visual Symptoms:				
	Lag in visual functions	32	1	25	58
	Hazy, blurring, or greyness	39	7	13	59
	Narrowing of visual fields	7	46	7	60
	"Curtain" effect	12	45	1	58
	Color aura phenomena	8	48	-	56
	Scotomata (blind spots)	14	42	-	56
	Alterations in ability to focus	9*	24	11	44
II.	Impairment in hearing	13	39	4	56
III.	Feeling of Confusion (disorientation or impairment in mental processes)	21	33	1	55
IV.	Instances of Faintness	5	48	3	56
V.	Other Symptoms:				
	Numbing of limbs or facial muscles	4			
	Pulling on viscera	5			
	Metallic taste in mouth	1			
	Soreness in back	1			

*One reported early loss of ability to focus; three reported blurring of distant objects; three, blurring of near objects; and in two cases the focusing power was impaired.

The varieties of visual and cerebral disturbances reported by the pilots during centrifugal acceleration provide clues which suggest that various physiological mechanisms are involved. The three which are probably most important, i.e., (a) venous pooling, (2) direct gravimetric effect on the arterial column, and (c) direct mechanical effect on the brain and eyes, will be briefly discussed below.

The Effects of Venous Pooling. Centrifugal acceleration influences the tendency of the venous blood to pool in the dependent portions of the body resulting in embarrassment of the cerebral circulation and consequent symptoms of general cerebral anemia such as euphoria, dizziness, fainting, confusion, and impairment of hearing and vision. Venous pooling does not occur instantaneously since several seconds are required for the blood to collect in the lower extremeties and the cardiac output to be reduced. Eleven pilots who stated that they blacked out easily during prolonged mild acceleration reported that their experiences were characterized by some of the above symptoms of general cerebral anemia. Out of the 16 pilots who stated that they were blacked out during sharp quick pull-outs, only 6 reported such symptoms in comparison to 10 who reported only visual symptoms. Venous pooling seems to contribute most acutely to blackout following prolonged acceleration, and

the impairment of vision frequently occurring may be considered one of the concomitant symptoms of a general cerebral circulatory disturbance.

The Direct Effect on the Arterial Column. The direct effect of increased acceleration on the arterial column of blood reaching from the heart to the head is an important aspect of venous pooling. Poppen[48] subjected experimental animals to centrifugal acceleration and noted that the drop in blood pressure in the carotid artery was proportional to acceleration until the effects of venous pooling began to occur. The effect of gravity on the arterial column of blood can be expressed mathematically in terms of g which gives the value of critical acceleration above which cardiac pressure will be unable to raise the blood as high as the brain. The formula for the calculation of g is given as 13.6 x p/1.060 x d, where 13.6 is the specific gravity of mercury, p the systolic blood pressure in centimeters of mercury, d the vertical distance in centimeters from the left ventricle of the heart to the brain, and 1.060 the specific gravity of the blood. From this formula it is apparent that the maintenance of cerebral circulation in the face of centrifugal acceleration will be favored by a high blood pressure and by a short vertical heart-brain distance.

Direct Mechanical Effects on Brain and Eyes. A toy balloon filled with water and placed on the table will flatten out, losing its spherical contour. A similar effect will take place in the eyeball when the organism is subjected to centrifugal acceleration. Accelerations of 8 or 10 g's would have the effect of a fluid 8 or 10 times as dense as the aqueous and vitreous humors of the eye globe. Two of the pilots indicated that early in the pull-out there was a phase when they could focus their eyes sharply on near objects but that distant objects appeared blurred. A flattening of the eye during acceleration would lengthen the anterior-posterior axis of the eye and tend to produce such symptoms; a temporary slight downward dislocation of the lens would also cause blurring. Whether this distortion contributes materially to the general blurring of vision reported by many of the pilots interviewed is problematical.

The brain is loosely attached to the inside of the cranium so that it can be moved about within the cranial cavity with an accompanying displacement of the surrounding cerebrospinal fluid. With increased centrifugal acceleration the brain probably tends to be displaced downwards, with increasing force on the floor of the cranial cavity, resulting in embarrassment of the capillary blood flow in these areas. Such disturbances would at first irritate and interfere with the function of structures like the olfactory bulb, the uncus, the optic chiasma and tracts, and the visual association areas. The pilots reported a definite color aura and dancing sparks before the eyes preliminary to complete loss of vision during the pull-out. These irritative phenomena are logically expected to follow pressure on one or more of the visual systems. Nine of the pilots specifically mentioned that the upper part of their visual fields was lost first, darkening proceeding from above downwards like a curtain. Eight of the pilots reported that as their vision faded away, they perceived dark spots,

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[48] Poppen, J. R. Discussion of paper by Armstrong and Heim. Op. cit., p. 62. (Footnote 47.)

suggesting perhaps the scattering of minimal focal areas of ischemia along one or more portions of the optic pathways. The neurological mechanisms involved in these phenomena cannot be located with certainty and it is probable that more than one mechanism is involved in these physiological disturbances.

Intercorrelations. As indicated earlier, one of the chief interests in this study centered in correlating the stated tolerance for centrifugal acceleration with a series of physiological measurements which had been made on each pilot. Appendix F shows the resulting intercorrelations between the various physiological measures and each of the others. The last three columns at the right in the table show the stated tolerance, the theoretical tolerance based on systolic blood pressure, fitting, and the theoretical tolerance based on the minimum systolic blood pressure in the reclining position. The highest correlations (greater than .20) obtained between stated tolerance and the physiological variables are as follows:

1.	Nipple-ear distance	-.35
2.	Smallest pulse pressure after tilt	+.32
3.	Minimum systolic blood pressure during tilt	+.27
4.	Time to smallest pulse pressure during tilt	-.25
5.	Systolic blood pressure (carotid sinus)	+.25
6.	Maximum pulse rate change during tilt	-.23
7.	Height	-.21

It should be noted that the correlation between stated tolerance and theoretical tolerance based upon reclining blood pressure was +.41. Also, a number of the correlations between the theoretical tolerance and certain of the physiological variables are fairly high. This would naturally follow from the fact that the theoretical value is computed from these same variables, such as the systolic blood pressure and the nipple-ear distance.

It is interesting to study the intercorrelations in Table F-1, Appendix F, for other relationships. As might be expected, certain of the physiological variables are closely related because they measure the same components. Possibly the most interesting ones related to the somatotyping; for example, Ht./$\sqrt[3]{Wt.}$ (an index of thinness) has a correlation of -.70 with endomorphy and +.85 with ectomorphy. In regard to stated tolerance, endomorphy correlated +.15 and ectomorphy -.12.

In brief, the following findings have been revealed in the study of centrifugal acceleration. In the first place, the pilots' estimations of acceleration necessary to cause a "black-out" varied from 3½ to over 10 G, with the mode at 5½ G, which were distributed for the group according to a normal distribution curve. Secondly, the analysis of the subjective symptoms showed that the visual symptoms predominated but that numerous others were experienced. Third, the differences in response suggested that a number of physiological mechanisms were involved, especially venous pooling; the direct gravimetric effect on the arterial blood column; and the mechanical effects on the brain and eyes. Finally, the results were analyzed to determine, in a preliminary way, the relationships between certain body measures and the tendency to black out. These analyses suggested that a

pilot who was relatively short and had a short distance between his heart and brain and who had a high systolic blood pressure, showed less tendency to black out during high centrifugal acceleration. Although the correlations in these cases are too low to be of significance, there is the possibility that an analysis of cut-off points at the tails of the distributions of these measures might reveal a higher degree of association.

III. Electrocardiography, Response to Startle and Circulatory Reflexes

Electrocardiography. In this part of the investigation, electrocardiographic tracings were obtained on 836 cadets and 75 instructors, using four different leads. It was not anticipated that these tracings would be different in the successful pilots as compared with the washouts. There were other objectives in obtaining these tracings. In the first place, it seemed important to find out how many apparently healthy persons revealed significant electrocardiographic abnormalities. This study also afforded an excellent opportunity to establish reliable norms for a large number of healthy young men to be used in clinical medicine, as well as to have records available for each pilot for comparison at a later date, or after combat duty in the war. It was also necessary to have normal tracings to compare with the changes observed in the startle response, relating to emotional stability. This objective will be discussed more fully below under Startle Response.

Over 80 separate measurements have been made from the tracings on each subject. A number of the more important deflections or complexes have been analyzed statistically to determine the reliability of the measures and to observe any differences occurring between the successful pilots, washouts, and board appearances. Table 15 shows the mean and sigma for eight variables, based on Lead II, using one heart beat. In comparing 29 washouts in Part I with 303 of the parent population, the P-values of the chi-square did not reveal significant differences between the two groups. The same negative findings were also obtained in comparing 22 board appearances with the parent population. The reliability coefficients for repeat tests of those measures, for 25 pilots, are shown in the last column of Table 15. Three of these measures have a low reliability, suggesting that a mean of three beats rather than one beat might be used in order to obtain higher reliability.[49]

In the analysis of the 80 odd measurements mentioned above, it has been possible to re-evaluate the norms or range within which apparently normal records might be found. A number of distinctly abnormal electrocardiograms were obtained in this group of apparently healthy young men. A few instances will be given here based upon the analysis of the records by Dr. Ashton Graybiel.

1. Rhythm. In addition to a few instances of premature beats and shifting pacemaker which are of no pathologic significance, there was one instance of short P-R interval and wide QRS waves. Although this curious anomaly is not associated with any known type of structural heart disease, persons with this abnormality in conduction are prone

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[49]An intensive statistical analysis of electrocardiographic variables has been undertaken by Dr. Franzen, one of the authors, and will be presented at a later date.

TABLE 15

COMPARISON OF ELECTROCARDIOGRAPHIC MEASURES FOR PARENT POPULATION IN RELATION TO WASHOUTS AND BOARD APPEARANCES IN PART I
(Repeat reliability of measures for 25 cases)

	Parent Population**			Washouts		Board Appearances		Repeat Reliability (25 pilots)
	N	Mean	Sigma	N	P*	N	P*	
Average Pulse Rate	302	60.10	9.50	29	.18	21	.42	.14
Amplitude of P-Wave in Lead II	303	1.04	0.41	29	.71	22	.42	.67
Duration of P-Wave in Lead II	303	.09	.02	29	.46	22	.50	.33
Amplitude of R-Wave in Lead II	303	10.80	3.60	29	.76	22	.55	.91
Duration of QRS Complex	303	.09	.01	29	.26	22	.61	.77
Amplitude of S-Wave in Lead II	301	-1.26	1.12	29	.85	22	.30†	.83
Amplitude of T-Wave in Lead II	303	3.45	1.24	29	.30	22	.28	.69
Duration of T-Wave in Lead II	303	.08	.01	29	.80†	21	.29	.31

*The P-value of the chi-square showing the probability that Washouts and Board Appearances are significantly different from all pilots.

**Washouts and Board Appearances are included in Parent Population.

to attacks of paroxysmal tachycardia which may be temporarily incapacitating and should form an adequate basis for eliminating a pilot from active duty.

2. Partial Heart Block. (Long P-R Interval.) In 10 instances the P-R interval was greater than 0.20 sec. and in 3 instances it was greater than 0.22 sec.

3. Duration of the QRS Complex. This is one of the most important measurements to be made from the electrocardiogram. The upper limit of normal in adults is usually considered to be 0.10 sec., and a duration of 0.12 sec. or more indicates bundle branch block. In 24 subjects the duration of the QRS complex measures 0.11 sec. and in 7 cases 0.12 sec. It is probable that 0.11 sec. should be considered within the normal range. However, a duration of 0.12 sec. should raise the question of heart disease.

4. Amplitude of QRS Complex. If the amplitude of the chief deflection of the QRS complex in three standard leads does not exceed 5 mm., low voltage is said to be present. Low voltage is usually associated with heart disease but may be present as a variation within the normal range. Ten instances of low voltage were found.

5. Low Voltage of the T-Waves. It is generally agreed that normally the T-waves should be upright in Lead I and at least 1 mm. in amplitude (unless there is a tendency toward right axis deviation with small R_1 and prominent S_1) and upright in Lead II and at least 1.5 - 2 mm. in amplitude. We observed one instance of inversion of the T-waves in Leads I and II, nine instances where the T-waves in both Leads I and II were less than 1.5 mm., eleven instances where the T-waves in Lead I were less than 1.0 mm., and twenty-three instances where the T-waves in Lead II were less than 1.5 mm. There are many factors in addition to heart disease which may cause lowering or even inversion of the T-waves, but such cases deserve special attention. (See below in startle pattern.)

Response to Startle (pistol shot). Measurements of the startle pattern on the electrocardiographic records were made on approximately 400 successful pilots and 60 washouts in classes 147-154, relating to (1) pulse rate after startle, at 6 second intervals up to 36 seconds; (2) somatic tremors: total duration, initial amplitude, and amplitude three-fifths seconds after the startle; and (3) alterations in T-waves: time of onset, maximum change in amplitude, and persistence of T-wave change. The data for these measurements are shown in Table 4, giving the means and standard deviations. The critical ratios and the P-values for chi-square in comparing the successful pilots with the washouts are shown in Tables 7 and 8.

The results may be briefly summarized as follows: (1) The tests individually or collectively did not distinguish the successful pilots from the poor ones in that the critical ratios and P-values were not significant. (2) Although for six seconds after the startle the average pulse rate for the washouts was greater than for the successful pilots, the difference was

too small to be of any significance. Also, the total duration of the somatic tremor after startle and the alterations in T-waves (for three variables measured, see Table 4) was greater for the washouts than for the successes. But, again, these differences were not significant. (3) Information was obtained from this analysis, especially that relating to the changes in the pacemaker and the lowering of the T-waves. The frequency with which the T-wave changes occur has been considered of importance in showing that such variations might be attributable to emotional factors rather than to heart disease. A lowering of the T-waves occurred in 7 out of 370 cases of successful pilots, or 1.9%, and in 1 out of 59 washouts, or 1.7% of the cases. There were alterations in the T-wave in 30 out of 370 good pilots, or 8.1%; and in 6 out of 59 washouts, or 10.2%.

Carotid Sinus Sensitivity. It was not possible to give this test routinely to all the pilots, so only a selected group was studied; i.e., 175 good pilots, 29 washouts, and 12 board appearances. None of the pilots actually fainted during the course of the test, but 0.6% of the good pilots felt "dizzy" or disoriented. None of the washouts or board appearances either reported or manifested such feelings. In Fig. 22, the systolic and diastolic blood pressures during stimulation of the carotid sinus of the two groups are shown graphically. Individuals with abnormal carotid sinus sensitivity might be expected to show a marked drop in blood pressure or pulse rate when the carotid sinus is stimulated. Only a few of these pilots showed a marked depressor response; in fact, the average data indicate a slight increase in blood pressure, perhaps due to an increase in muscular tension. The washouts as a group showed a higher initial and slightly greater increase in systolic blood pressure than the successes. The changes, in both systolic and diastolic blood pressure, were not considered to be significant. The electrocardiographic tracings, which have not been analyzed in detail, showed only minor changes. No evidence was obtained in this part of the study that the responses of the two groups differed, nor were they very revealing concerning susceptibility to fainting among these normal young men.

Cold Pressor Test. All of the cadets in Part I of the study were given the cold pressor test. The average increases in systolic and diastolic blood pressures for the successes and washouts are shown in Fig. 22. In most cases there was an increase in systolic pressure of approximately 20 - 25 mm. Hg and a rise of similar proportion in diastolic pressure. The average increase in both readings was greater for the washouts than for the successful pilots. The critical ratio for the greatest diastolic change was 2.26, for the greatest systolic change 1.68 (see Table 7). An analysis of the results for individuals in both groups showed that 8 of the 175 good pilots, or 4.5%, showed an increase in systolic pressure to 150 or above, while 3 of the 29 washouts, or 10.4%, showed a similar rise. There was only one cadet whose systolic pressure rose above 185, and he was in the group of successful pilots.

Skin Resistance Test.[50] Only a representative group of subjects took this test. The results did not differentiate the washouts from the successful pilots

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50The data obtained with this test by Dr. Robert Phillips, with equipment from the Rockefeller Institute in New York, were of interest in the form of giving additional information to that which was obtained in the clinical examination and other physiological tests relating to emotional stability.

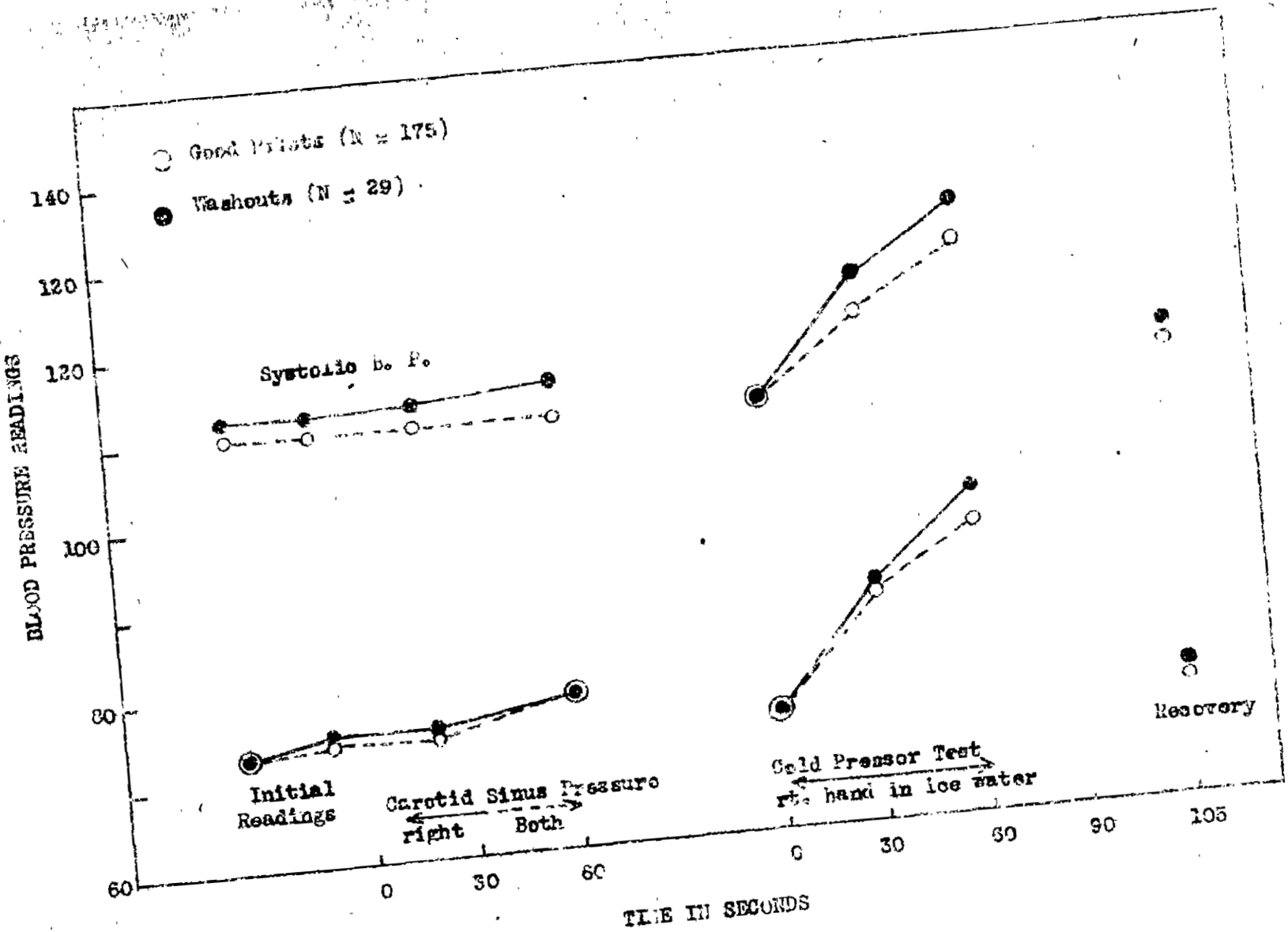

Figure 22

Records of the Systolic and Diastolic Blood Pressures for Good Pilots and Washouts during Stimulation of the Carotid Sinus and the application of the Cold Pressor Test.

although the test gave objective evidence of more extreme responses in certain pilots who were having difficulty in flying. Difficulty was experienced in obtaining a common baseline at the beginning of each experiment. It was necessary, therefore, to assign arbitrary numbers to the amount of resistance at intervals of 5000 ohms on the galvanometer so that a score based upon the percentage of change when the hand was placed in ice water could be assigned to each subject. In this way it was possible to compare the good pilots with the poor ones to see if the average response of the poorer ones was greater than in the successful group. The results obtained with such an experimental and scoring procedure are shown in Table 16. A larger percentage[51] of the

TABLE 16

RESULTS ON SKIN RESISTANCE TEST

Percentage Change in Resistance (ohms)	Good Pilots		Board Appearances		Washouts	
	N	%	N	%	N	%
0 - 19	50	51.6	3	42.9	4	26.7
20 - 39	29	30.0	2	28.6	2	13.3
40 - 59	17	17.6	2	28.6	8	53.3
60 - 74	1	1.0	-	-	1	6.6
N	97		7		15	

washouts showed a more extreme response in terms of skin resistance than the successful ones - i.e., over 50% of the former group fell within the group which showed 40% - 59% change; 18% of the good pilots fell within the range. It will be necessary to standardize the test more completely before considering it for use in pilot selection programs.

IV. [illegible] Psychophysiological Studies

Electroencephalography (brain waves - Grass apparatus). The electrical activity of the brain was recorded in all of the cadets in Part I and II of this investigation. The results have been reported separately, using [illegible] different methods in treating the data.[52] In this report, the data have been treated by the same statistical procedures as were used with all the other tests given in the series at Randolph. The different phases of this [illegible] have been studied have been described in Table [illegible]. The present report simply takes into account important changes which have occurred in electroencephalography up to 1940.

[illegible] Caution must be exercised in interpreting [illegible] based on [illegible] than 200.

[illegible] (Footnote 52)

The critical ratios of the means and P-values for the two distributions are shown in Tables 7 and 8 for the various groupings. In general, the critical ratios are low and the P-values are high.

The Part I records were scored by two judges independently (H. Davis and E. Beresford) on a scale from 1 to 5, and the Part II records by E. Beresford alone. The highest rating is 1 (alpha rhythms of 8 to 12.9 cycles per second) and is that most frequently found in normal young men. These alpha rhythms indicate the most stable and most smoothly functioning cerebral cortex. The last two ratings, 4 through 5, represent dysrhythmias, or abnormalities which suggest instability. The most extreme are associated with a number of conditions often termed epileptoid or psychomotor equivalents.

An analysis of the results in Table 17 shows that the majority of the brain wave patterns of the Pensacola cadets were of the orderly and stable types which have been observed most frequently in healthy, well-balanced persons. Many of the records, however, revealed the irregular patterns that are similar to those associated with epilepsy. No significant relationships exist between the ratings on the stability scale and flight performance, judged in terms of successful pilots, and washouts or board appearances.

TABLE 17

FINAL RATINGS OF BRAIN WAVE PATTERNS

Percentage of Cadets in Each Group

Part I

Rating	Good Pilots		Successes		Washouts plus Board Appearances		Washouts	
	N	%	N	%	N	%	N	%
1	46	16.0	51	16.9	8	11.9	3	8.3
2	143	49.7	160	50.1	40	59.7	23	63.9
3	78	27.1	86	27.0	15	22.4	7	19.4
4	21	7.3	22	6.9	4	6.0	3	8.3
	288		319		67		36	

Part II

1	60	17.2	66	16.1	20	16.1	14	22.2
2	180	51.7	220	53.8	71	57.2	31	49.3
3	85	24.4	97	23.7	28	22.6	16	25.4
4	23	6.6	26	6.4	4	3.2	1	1.6
5	-	-	-	-	1	0.8	1	1.6
	348		409		124		63	

with the exception of a few extreme cases. In Part I of Table 17, for instance, the percentage is approximately the same in all groups in the poorest category (i.e., those rating 4). In Part II a similar trend is observed with the exception that the percentage of those rating 4 or 5 in the washout group is actually less than in the successful group. An attempt was made to devise a method of scoring the records which would yield a distinction between failures and successes. With 63 cases of known failures and 202 cadets who passed the course, a method of rating was devised (Forbes' modification of the Brazier rating; see Fig. 2 in reference cited in Footnote 31) which gave a biserial correlation coefficient of 0.27. This relationship was not upheld on subsequent series. The further investigation and possible use of the electroencephalogram as a selective device is contingent upon the development of a reliable scoring technique that yields statistically significant results in differentiating successes from failures.

Body Build (somatotype - Sheldon's method). An analysis of the data in Part I indicated that the relative occurrence of the various somatotypes at Pensacola was strikingly different from that found in the general college population. A comparison between 364 cadets and 4,000 cases drawn from five universities is shown in Table 18. An analysis of the data in this table shows significant differences between the cadets and college students. The cadets are predominantly mesomorphs,[53] and certain of the more massive somatotypes which are scarce among college students are found to be of frequent occurrence among the cadets. More detailed analysis reveals several other differences. For instance, individuals in whom mesomorphy is the lowest component (group 3 plus group 8, in Table 18 below) are more than five times more numerous in colleges than at Pensacola.

TABLE 18

RELATIVE OCCURRENCE OF VARIOUS SOMATOTYPES IN CADETS COMPARED WITH THE GENERAL COLLEGE POPULATION

		Pensacola (N = 364)	College (N = 4,000)
1.	Endomorphs	2.0	5.9
2.	Mesomorphic-endomorphs	5.0	6.0
3.	Ectomorphic-endomorphs	0.5	3.25
4.	Mesomorphs	12.6	13.2
5.	Endomorphic-mesomorphs	17.9	8.55
6.	Ectomorphic-mesomorphs	15.2	8.8
7.	Ectomorphs	5.3	13.0
8.	Endomorphic-ectomorphs	1.0	4.5
9.	Mesomorphic-ectomorphs	9.9	9.2
10.	Balanced	30.4	27.55
		(99.80)	(99.95)

[53] Editor's Note. In this connection, it is interesting to note that in the selection of applicants for flight training, there appears to be a possibly unintentional bias in favor of the mesomorphic type.

Also, of the total 76 somatotypes occurring in the college (and general) population, 35, or almost half, are missing at Pensacola. These somatotypes contain nearly 20% of the college population. It is clear that, under standards of selection operating at the time of this study, a large proportion of the college population was being excluded from the air service.

A statistical analysis has been made of the somatotypes recorded by Drs. W. H. Sheldon and S. S. Stevens for the cadets in Parts I and II. These data were treated in the same manner as all other tests in the series. Each component was dealt with separately. This procedure may be questioned, since it is the relationship which exists among these three components as a composite grouping, rather than each individually, which might be treated in relation to success in flying. A numerical score cannot be given to represent these three components as a unit, however, since they simply refer to points on a tri-dimensional scale.

When somatotype measures are evaluated in combination, definite relations between certain combinations and the washout criterion appear. The method used was to divide each of the three components so that approximately one-fifth were at the lower end of the distribution, one-eighth at the upper end of the distribution, and two-thirds at the middle. These divisions were arbitrarily chosen by inspection of the distributions. This, then, allowed three divisions for each component, giving 27 combinations. Some of them had no frequency. Some of those that did have frequencies, however, when used together, yielded P-values under 0.03. The classifications which distinguished washouts from retained cadets were:

Low on mesomorphy and in the middle two-thirds of the other two measures.
Low on endomorphy and in the middle two-thirds of the other two measures.
Low on ectomorphy and in the middle two-thirds of the other two measures.
Low on mesomorphy, high on endomorphy, and in the middle two-thirds of ectomorphy.
Low on ectomorphy, high on endomorphy, and in the middle two-thirds of mesomorphy.

The opposites of these, that is changing high on a factor into low, low on a factor into high, and leaving average as it is, yield a prediction of the opposite sort, that is, they will insure the selection of retained cadets and predispose against selection of washouts. Use of dysplasia, in addition to the three basic measures, increases the relation even further.

This conclusion cannot be regarded as of any practical importance since the group was highly selected to begin with. It is possible that the observed relationship between washouts and somatotypes is due to preconceived physical standards held by those who select pilots.

Several additional procedures have been used in an analysis of these data. One method was as follows: the individual components of the three different somatotypes have been compared for the successes and washouts. The results are shown in Tables 7 and 8. The data for dysplasia are also shown in these tables. None of the critical ratios of the differences between means reaches the desired level of 3.0 and the P-values of the chi-

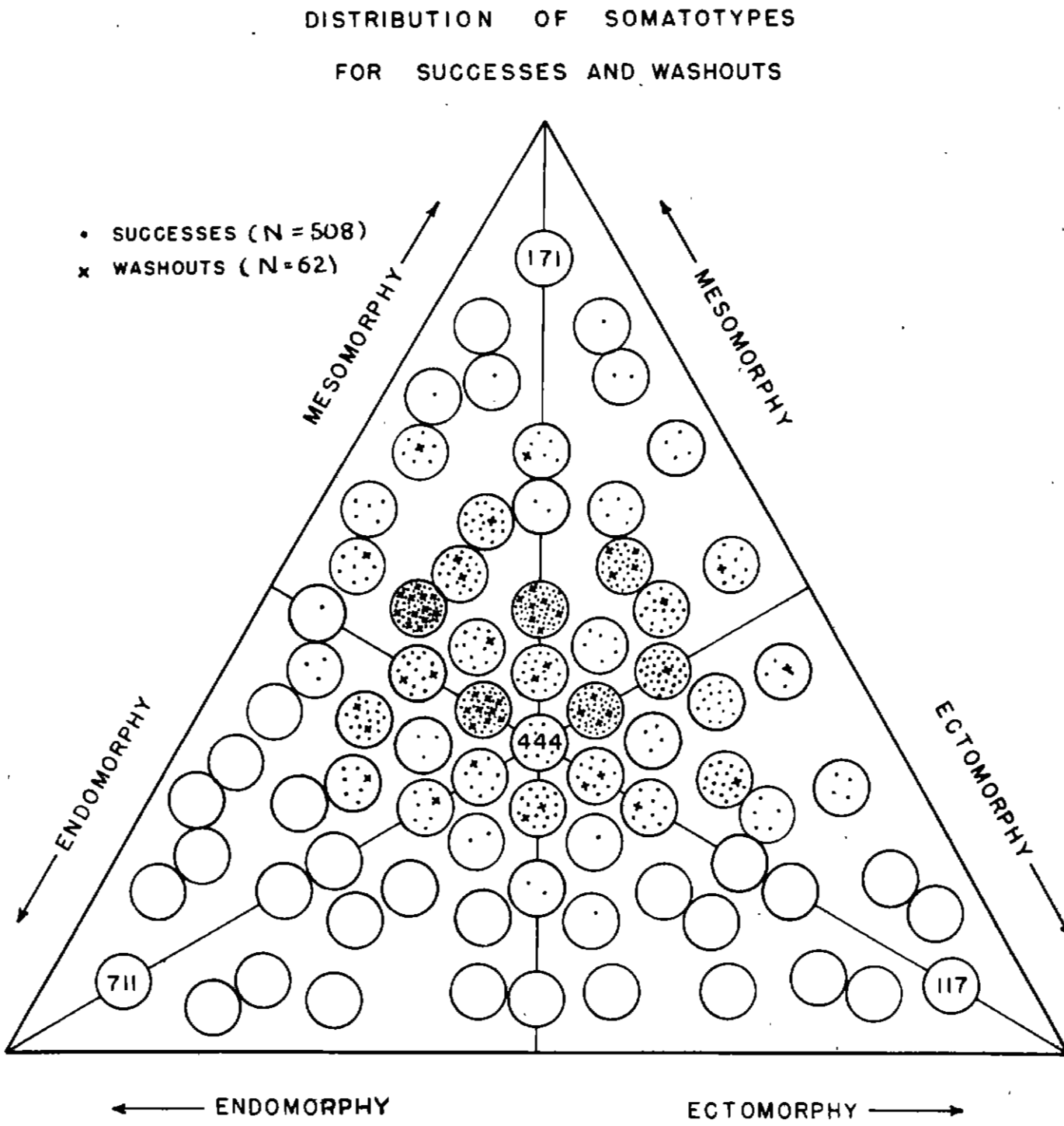
DISTRIBUTION OF SOMATOTYPES
FOR SUCCESSES AND WASHOUTS
• SUCCESSES (N = 508)
× WASHOUTS (N = 62)
MESOMORPHY
MESOMORPHY
171
ENDOMORPHY
ECTOMORPHY
444
711
117
ENDOMORPHY
ECTOMORPHY

Figure 23

square test of the distributions are consistently high, indicating that there are no significant differences between the successful pilots and the washouts for those three individual components. If a critical ratio of 2.0 is considered as identifying a possible trend, the results suggest that cadets predominating in endomorphy tend to be washouts and those predominating in ectomorphy tend to be found more frequently among the successes. The somatotype found most frequently at Pensacola, however, was the mesomorphic and the critical ratios for this component were consistently low.

A second method was used in the analysis of the data which may be considered by the authors of the somatotyping technique as more adaptable in the treatment of the data than the statistical procedures mentioned above. As the authors point out, "any individual in the population at large has varying degrees of endomorphy, mesomorphy, and ectomorphy, and it is possible to rank order a given sample of the population against each of its aspects. Although only discrete gradations of an aspect can occur in as finite a population, as the Pensacola cadets, the gradations are sufficiently fine to warrant the assumptions that the aspects can be regarded as continuous variables." Hence, Sheldon postulates "continuity in the gradation of each component" and proceeds to treat them as "continuous variables" on a tridimensional scale.[54] Thus, along each of the three axes at right angles to one another, the numerals from 1 to 7 for each of the somatotype scales can be plotted. This plotting has been done for the cadets of Parts I and II on a schematic two-dimensional projection of the theoretical spatial relationships among the known somatotypes.[55] The somatotype for each cadet was plotted according to this scheme to see if the group as a whole tended to cluster in one area and, furthermore, whether the washouts were equally distributed, or whether they tended to fall in a distinctive or separate area. The results are shown in Fig. 23. The circles represent successes, and the crosses, washouts. The successes, as a whole, tended to be grouped with those having predominantly mesomorphic characteristics. The washouts, however, appear to be fairly well distributed throughout this same grouping. There is a tendency for the poor pilots to be high in endomorphy, but it is questionable whether these differences are significant.

In considering these results, it should be kept in mind that the group was a very homogeneous one with little spread in the individual components. A more heterogeneous group, as might be found at the time of original selection at the elimination bases, would have given a fairer test of the hypothesis that certain physiological types succeed in flying.

Although the results of this method proved to be negative from the point of view of differentiating the successful pilots from the washouts in the cadets studied at Pensacola, one very interesting observation can be made in regard to these data relating to human physique. The physicians and selection boards have tended to pick out the athletic type of individual (predominating in mesomorphy). As pointed out above, a large proportion

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[54] Sheldon, W. H., Stevens, S. S., and Tucker, W. B. P. 112. Op. cit. (Footnote 32.)

[55] Sheldon, W. H. and Stevens, S. S. P. 375. Op. cit. (Footnote 33.)

of the average college population would be eliminated on such a basis. Thus, although the athletic type of individual may excel in motor coordination and characteristics for "officer material," many individuals may have been eliminated who excel in other, and equally important, psychological traits, such as courage in combat, and love of fighting, which may be even more important in war time.

Results Obtained on Pensacola Instructors

During the course of the investigation, a group of flight instructors at the Naval Air Station were given most of the psychological and physiological tests. The purpose of this part of the study was to obtain data from pilots known to be successful. Also, many of them had expressed interest in the investigation and had requested that they be given the series of tests. Eighty-three of the instructors at the Station volunteered to take the tests. Their mean age was 27, with an average of 1,500 flying hours. The results are of interest for the following reasons: In the first place, pilots who have been outstanding in their success in flying should make high scores in relation to the group classified as good or successful pilots in this study. This is especially true in the motor coordination tests, in spite of the difference in age, i.e., the instructors were on the average five years older than the cadets. In the second place, the data from the instructors should be of some assistance in evaluating certain of the physiological measures. If it was found, for example, that many of the instructors showed extreme reactions in the startle pattern, very abnormal breathing patterns, low physical fitness, or many abnormalities in the brain waves, then it might be necessary to place a different emphasis on the importance of these tests from the point of view of selection. The instructors as a group were outstanding pilots. After the war started a large percentage of them were transferred to combat duty. Many of them have played an active part in flight operations, especially at Midway and in other aerial encounters in the Pacific area.

The results obtained for the instructors are shown in Table 19. In order to compare their scores with a representative group of cadets, the data for the successes in Part I (washouts excluded) are also shown in the same table. In the tests, where the means of the instructors are better, or the standard deviations lower, the figures have been underlined. In general, the results are surprisingly similar. The critical ratios are shown in the last column. The results of the physiological tests for the two groups are also similar. The instructors made better scores in the Schneider Index, and they also had larger mean Tidal Air Volume, slightly higher systolic and diastolic blood pressure, and faster resting pulse rates. On the Tilt Table Test the instructors were somewhat more stable, i.e., they showed slightly less variation in response than the cadets, as judged by both the means and standard deviations.

The results for electrocardiography and electroencephalography for the instructors are presented in Table 20. The results from the electrocardiographic tracings were on the average within the normal range of variation. There was one exception, i.e., a case of bundle branch block. This diagnosis is indicative of an important cardiac disorder. It has been contended

TABLE 19

COMPARISON OF INSTRUCTORS AND CADETS CLASSIFIED AS SUCCESSES IN THE PSYCHOLOGICAL AND PHYSIOLOGICAL TESTS

I. Psychological Tests:	N	Mean Inst.	Mean Succ.	Standard Deviation Inst.	Standard Deviation Succ.	C.R.m
Athletic Achievement (Thorndike-Kelley)	66	54.0	45.1	20.4	21.9	3.18
Eye-Hand Coordination	83	67.4	69.6	8.2	8.1	2.45
Two-Hand Coordination	83	58.2	56.0	11.9	12.0	0.14
Washburn Serial Action Test	82	5.9	5.0	0.8	1.0	1.17
Dotting (McDougall)	83	211.3	215.7	22.8	26.9	1.54
Continuous Reaction (Cattell):						
Part A (the slow strip)	67	446.7	427.8	77.2	81.2	1.80
Part B (the fast strip)	67	332.8	322.6	96.4	78.4	0.79
Parts A and B	67	772.9	758.0	166.3	141.8	0.68
Ataxiameter (mean of eyes closed)	83	460.2	441.9	131.1	118.6	1.16
Perception of Change in Position	83	20.9	23.6	8.9	9.6	2.42
II. Physiological Tests:						
Basal Metabolic Rate	79	-3.4	+0.5	11.4	12.7	2.64
Tidal Air/Body Surface	79	422.2	374.7	98.0	120.6	3.71
Vital Capacity	77	5290.0	5258.4	747.0	700.5	0.34
Vital Capacity/Body Surface	75	2764.9	2790.3	376.0	320.0	0.64
Schneider Index of Neurocirculatory Fitness	83	11.0	9.6	2.9	3.7	3.50
Tilt Table:						
Systolic Blood Pressure (reclining)	84	121.0	115.1	8.6	8.0	6.02
Diastolic Blood Pressure (reclining)	84	75.9	70.3	8.1	7.8	5.71
Pulse Rate (reclining)	84	71.9	66.2	8.0	8.1	5.82
Pulse Pressure Change	80	30.8	30.4	8.7	10.3	0.34
Pulse Rate Change	80	33.4	37.9	9.4	10.0	3.85
Smallest Pulse Pressure	80	15.4	17.2	6.4	7.9	2.22
Time to Smallest Pulse Pressure	80	11.1	12.2	6.2	5.9	1.46

Note 1: The cadets are composed of the group classified as successes in the tables; i.e., Washouts are excluded in the means.

Note 2. The means of the instructors are underlined wherever they are better than the cadets, and the standard deviations wherever they are lower than the cadets.

TABLE 20

RESULTS OF ELECTROCARDIOGRAPHY AND ELECTROENCEPHALOGRAPHY FOR PENSACOLA INSTRUCTORS

Electrocardiography		Electroencephalography		
EKG Measures	Number of Subjects	Range Rating	Number of Subjects	
Normal	72	1+	4	
Shifting pacemaker	2	1	6	10
Long P-R interval	1	1-	0	
Many premature beats	1			
Startle - CSP vent,		2+	8	
escape nodal effects		2	11	28
through ectopic beats	1	2-	9	
Minor variations in				
startle pattern	5	3+	4	
Low T in startle test	2	3	4	26
Bundle branch block	1	3-	18	
		4	0	
		4	1	3
		4-	2	

that individuals with such a diagnosis should be disqualified from flying, because of a relatively poor prognosis, although cases thereof may remain well for many years. In the study of the brain waves on the basis of the ratings from 1+ (the highest score) to 4- (the lowest possible score), it was interesting to find that so many of the instructors fell within the next to the poorest category and three in the very poorest, the latter cases having brain waves similar to those observed in clinical cases diagnosed as epileptic. It will be recalled, as indicated above, that a large number of abnormal records were also found in the cadets who succeeded in passing the course (see Table 17). Questions naturally arise concerning the potential usefulness of this test in selecting pilots when abnormalities are observed so frequently among pilots known to be successful.

SUMMARY ANALYSIS OF SELECTED PHYSIOLOGICAL TESTS

A brief summary will be given of the results obtained with the data relating to Breathing Pattern, Tilt Table Variables, Brain Waves, and Somatotyping. One purpose of this analysis was to select the most reliable from a large number of items in each of these tests. In addition, it was necessary to determine the extent to which the various items were interrelated, as well as their value in differentiating the washouts from the parent population.

Breathing Pattern.[56] Twenty-three different items were measured on the

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[56] A more complete discussion of these respiratory variables may be found in: Franzen, R. A. and Blaine, L. Op. cit. Some of the material in this section, including Table 21, is reproduced from this report.

breathing patterns from the metabolism charts in an attempt to select the most reliable indices for scoring the records (see Fig. 10A). Eight were finally selected for statistical treatment as follows: tidal air (mean), tidal air (sigma), duration (mean), inspiration (mean), number of respiratory cycles per minute, vital capacity, oxygen consumption, and minute volume. This number was finally reduced to five on the basis of the following criteria: (a) test - retest reliability, and (b) independence of function, both physiologically and mathematically. The most significant and independent functions in this series proved to be (1) the mean of tidal air, (2) the sigma of tidal air, (3) the number of respiratory cycles per minute, (4) vital capacity, and (5) oxygen consumption.

TABLE 21

INTERCORRELATIONS AND RELIABILITIES OF FIVE SELECTED RESPIRATION VARIABLES

Test	Tidal Air (Mean)	Tidal Air (Sigma)	Number of Respiratory Cycles per minute	Oxygen Consumption per minute	Vital Capacity
		Part I			
	(N = 215 for intercorrelations; N = 100 for reliabilities)				
Tidal Air (Mean)	(.75)				
Tidal Air (Sigma)	.50	(.76)			
Number of Respiratory Cycles per minute	.53	.38	(.84)		
Oxygen Consumption per minute	.06	.14	.01	(.70)	
Vital Capacity	.18	.12	.15	.08	(.89)
Mean	410 cc.	77 cc.	10.4	268.5 cc.	2798 cc.
Sigma	155 cc.	44 cc.	3.4	44.8 cc.	344 cc.
		Part II			
		(N = 371)			
Tidal Air (Mean)	(.87)				
Tidal Air (Sigma)	.54	(.64)			
Number of Respiratory Cycles per minute	.47	.35	(.87)		
Oxygen Consumption per minute	.27	.18	-.01	(.70)	
Vital Capacity	.22	.10	.12	.28	(.87)
Mean	463 cc.	74 cc.	11.2	257.5 cc.	2761 cc.
Sigma	154 cc.	41 cc.	3.2	31.8 cc.	349 cc.

The intercorrelations of these five respiratory variables are shown in Table 21. With the exception of the oxygen consumption, the correlations are practically identical in both Parts I and II. Such stability of relationship is evidence that the measures involved reflect definite physiological differences among individuals. It is obvious from inspection of this table that

there is a factor common to tidal air (mean), tidal air (sigma), and the number of respiratory cycles per minute. It is also probable, though not so clear, that vital capacity and oxygen consumption are independent (i.e., factors in themselves). This judgment was confirmed by multiple factor analysis.

Correlations were also made (both r's and eta's) for each of the five respiratory measures with each of the measures of the tests relating to somatotypes, brain waves, and tilt table. The striking finding about these manifolds is the total absence of relationship. All of the r's are under 0.2, and only four of the eta's are as high as 0.3. Selected characteristics of the respiration were uncorrelated with both somatotypes and brain waves. These two are themselves uncorrelated. If they measure types, they measure three different kinds of types. The respiration measures show no relation to the 13 tilt table variables.

The next step in the analysis was to obtain information as to the probability that the washouts for aptitude are not significantly different from all pilots in their scores on each of the tests of respiration. The P-values for both Parts I and II comparing washouts with the parent population are shown in Table 22.

TABLE 22

THE PROBABILITY THAT WASHOUTS FOR APTITUDE ARE NOT SIGNIFICANTLY DIFFERENT FROM ALL PILOTS IN THEIR SCORES ON EACH OF THE RESPIRATION TESTS

Part I	P-Value	N of Washouts	N of Parent Distribution
Tidal Air (Mean)	.25	36	299
Tidal Air (Sigma)	.62	36	299
Number of Respiratory Cycles per minute	.06	36	299
Oxygen Consumption per minute	.82	27	282
Vital Capacity	.10	34	294
Part II			
Tidal Air (Mean)	.11	60	371
Tidal Air (Sigma)	.93	60	371
Number of Respiratory Cycles per minute	.93	60	371
Oxygen Consumption per minute	.03	60	371
Vital Capacity	.79	60	371

The data are not always consistent. For instance, the washouts in Part I differ in number of respiratory cycles per minute, but those in Part II definitely do not. A similar reversal of trend is noticed in regard to oxygen consumption per minute. The washouts in Part II are significantly different in oxygen consumption per minute from the total group but those in Part I are not. In Part II the washouts were more likely to have very large and very small oxygen usage, and average oxygen consumption was less characteristic of their breathing. Tidal Air (mean) has a low but not significantly

low P-value in both samples. The hand pressure in Part I data is the rate of breathing measured by numbers of cycles.

From these data one cannot accept any of the measures as a means of distinguishing flying aptitude. Inspection of the observed and expected distributions of washouts used in obtaining the chi-square values suggested that respiration measures extended over a period of time might reveal better predictive value in these respiration measures.

Tilt Table Test. A more extensive analysis of the data from the tilt table test has been made for 13 different variables as listed in Table 23. Each test was correlated with every other one, and the significance of the difference was calculated between the distribution of washouts and the parent population. The intercorrelations of each of the 13 tests with every other is shown in Table 23. From the nature of these different measures of the same cardiovascular reaction, one would expect to find correlation among them if the measurements are functions of the individual. It is, however, only the most obviously related measures that exhibit any significant coefficient of either linear or curvilinear correlation. Only two of these, change in pulse rate on being tilted and maximum pulse rate during the test, have sufficient correlation to suggest evaluation of the same function. The initial and maximum change in both systolic and diastolic blood pressures have r's as low as 0.6 and 0.5, respectively. Initial and maximum pulse rates correlate only 0.3. The time intervals to maximum and minimum measures are consistently unrelated to any of the other measures or to each other.

These low correlations may be due to the lack of reliability in the measurements. A test may be accurate (as a measure of biological instant) and still unreliable as a measure of the average physiological function of the individual. Further, the physiological state of the individual at a particular time may be properly described, but the individual still may not be placed in his true relation to others. Reliable definition of individual differences is a prerequisite to correlation.

The positive and negative nature of the correlations must, of course, be considered in terms of the scoring arrangements of the tests involved. In the case of smallest pulse pressure when correlated with pulse pressure change and with maximum systolic change, for instance, the negative relation implies that there is a tendency, when the smallest pulse pressure is smaller than usual, for the pulse pressure change and the maximum systolic change to be larger than usual. This relationship would be greater with a larger variance in the sampling of individual scores.

When the scores of the washouts are compared with those of other pilots, it is possible to evaluate the extent to which any test distinguishes the washouts from the parent population. The P-value determined by chi-square is read as follows. Initial systolic change with a P-value of 0.48 gave scores to washouts sufficiently like the scores of all pilots so that 48 times out of 100 or about 1 out of 2 times would a difference as large as or larger than this occur by chance. The test cannot, therefore, be accepted as measuring a trait which distinguishes between success and failure in fly-

TABLE 23

r AND eta OF EACH TILT TABLE TEST WITH EVERY OTHER
(N = 359)

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
(1) Pulse Pressure Change	r	----												
	eta													
(2) Pulse Rate Change	r	590	----											
	eta	602												
(3) Smallest Pulse Pressure	r	-341	-272	----										
	eta	374	305											
(4) Time Interval to Smallest P.P.	r	137	-036	-082	----									
	eta	197	135	175										
(5) Initial Systolic Change	r	-450	-226	309	-021	----								
	eta	450	528	361	224									
(6) Maximum Systolic Change	r	-476	-342	472	-039	560	----							
	eta	476	396	483	271	627								
(7) Time to Maximum Systolic Change	r	-035	-074	071	-250	-101	174	----						
	eta	197	161	235	330	229	249							
(8) Initial Diastolic Change	r	-308	022	046	009	-030	-095	-054	----					
	eta	367	189	201	190	166	241	168						
(9) Maximum Diastolic Change	r	-477	025	064	-240	-201	-170	-124	472	----				
	eta	486	279	224	349	215	249	192	632					
(10) Time to Maximum Diastolic Change	r	-111	060	-005	-276	083	-073	069	-001	256	----			
	eta	261	227	251	317	209	259	171	281	41[illegible]				
(11) Initial Pulse Rate Change	r	-174	-480	130	-055	189	218	060	096	05[illegible]	0001	----		
	eta	214	485	262	136	273	333	206	214	267	198			
(12) Maximum Pulse Rate	r	-155	-647	287	-018	109	261	-017	001	059	-071	319	----	
	eta	182	647	269	120	228	325	162	194	226	156	393		
(13) Time to Maximum Pulse Rate	r	-043	-252	021	022	088	-049	-0005	-003	-08[illegible]	-009	-105	087	----
	eta	194	281	204	114	190	202	143	178	29[illegible]	131	278	145	
Mean		28.4	57.5	17.9	13.1	7.6	15.1	6.2	11.1	22.[illegible]	12.4	17.2	103.9	7.8
Sigma		9.3	10.7	7.9	5.7	6.9	9.5	6.1	6.1	8.0	8.0	8.5	13.3	6.2

Note: The decimal points have been omitted for convenience in presenting the r's in this table.

ing. There is only one test, time interval to smallest pulse pressure, where the difference between washouts and all pilots is large enough to make it unlikely that it is due to chance. Between 5 and 6 times out of 100 (56 out of 1,000) would the chance difference of a sample be as large as the departure of the washout distribution from that of all pilots on this test. Inspection of the observed and expected distributions indicates that the washouts are more apt to have a short time interval to smallest pulse pressure than are all pilots. There are 14 washouts contrasted with 10.5 expected cases who are 0.7 or more standard deviations above the mean (low original scores) and 8 washouts with 12.3 expected cases who are 0.7 or more standard deviations below the mean (high original scores).

When the scores of pilots whose aptitude has been in question, but who have not been grounded (board appearances), are compared with all pilots, the only test making any real distinction is smallest pulse pressure (see Table 24). The measures of smallest pulse pressure put 23 of the selected group with 17.7 expected cases above the mean (low original scores) and 13 observed with 18.3 expected below the mean (high original scores). These differences when expressed in smaller intervals produced a chi-square of 11.24 which would occur by chance only 8 times out of 100. The P-value for washouts on this test was 0.25.

Although this one application of physical measures after the tilt table experience cannot give us reliable bases for test selection, the pulse pressure tests offer real possibilities and should be further validated. The other cardiovascular ratings, with the possible exception of time to maximum systolic change, apparently have little likelihood of pointing out flying handicaps. This analysis of the tilt table data suggests that: (1) there should be further study of tilt table materials which will include enough repeat tests to determine the variance of individuals over time; (2) tilt table measures, when given only once, do not promise values in selection; final validation rests on more extensive measurements for each pilot; (3) intercorrelations might offer the possibility of classifications by cardiovascular type (when reliable individual differences are determined), and these may be useful in maintenance problems.

Electroencephalography and Somatotyping. The various items used in these measurements in the brain wave and somatotyping are described earlier in the report (see pages 21, 22). The results will be reviewed for both the brain waves and somatotypes as well as the relationship between various items of these two tests. Tables 25 A, B, and C show the intercorrelations between (1) the items in the brain wave, (2) the items in the somatotyping, and (3) the intercorrelations between the brain wave measures and the somatotype measures.

In the case of the electroencephalogram, the four measures are seen to be unrelated, with the exception of Alpha Index and Voltage which are obviously functions of the same characteristic. The low negative relationship among the other variables points to their use as reflecting independent, and to some extent, mutually exclusive phenomena. The somatotype intercorrelations indicate a complementary use. With the exception of Dysplasia these r's are about as high as can occur in an entirely negative matrix. A high rating on

TABLE 24

THE PROBABILITY THAT WASHOUTS FOR APTITUDE AND PILOTS WHO HAVE HAD BOARD APPEARANCES ARE NOT SIGNIFICANTLY DIFFERENT FROM ALL PILOTS IN THEIR SCORES ON TILT TABLE TEST

Tilt Table Test	N of Parent Population	N of Washouts	N of Board Appearances	P Value: Washouts vs. Parent Population	P Value: Board Appearances vs Parent Population
Pulse Pressure Change	361	33	36	.68	.39
Pulse Rate Change	361	33	36	.78	.72
Smallest Pulse Pressure	361	33	36	.25	.08
Time to Smallest Pulse Pressure	361	33	36	.08	.79
Initial Systolic Change	361	34	36	.43	.45
Maximum Systolic Change	361	34	36	.73	.65
Time to Maximum Systolic Change	361	34	36	.49	.20
Initial Diastolic Change	361	34	36	.83	.55
Maximum Diastolic Change	361	34	36	.74	.14
Time to Maximum Diastolic Change	361	34	36	.56	.77
Initial Pulse Rate Change	361	34	36	.65	.76
Maximum Pulse Rate	361	34	36	.73	.49
Time to Maximum Pulse Rate	361	34	36	.75	.66

TABLE 25A

r and eta OF MAIN ELECTROENCEPHALOGRAM MEASURES WITH EVERY OTHER

	Voltage		Alpha Index		Alpha Frequencies		Abnormalities	
	r	eta	r	eta	r	eta	r	eta
Alpha Index	.80	.81						
Alpha Frequencies	-.22	.43	-.21	.30				
Abnormalities	.07	.20	-.20	.27	-.05	.24		
N	355		355		355		355	
Mean	20.1		98		41.3		2.6	
Sigma	7.5		551		5.9		1.8	

TABLE 25B

r AND eta OF EACH SOMATOTYPE MEASURE WITH EVERY OTHER

	Endomorphy		Mesomorphy		Ectomorphy		Dysplasia	
	r	eta	r	eta	r	eta	r	eta
Mesomorphy	-.27	.30						
Ectomorphy	-.50	.51	-.55	.59				
Dysplasia	.07	.23	.00	.13	.00	.25		
N	364		364		364		364	
Mean	6.3		8.7		6.5		15.3	
Sigma	1.9		1.7		2.1		3.1	

TABLE 25C

r AND eta OF SOMATOTYPE MEASURES WITH ELECTROENCEPHALOGRAM MEASURES

	Endomorphy		Mesomorphy		Ectomorphy		Dysplasia	
	r	eta	r	eta	r	eta	r	eta
Voltage	-.01	.13	.05	.11	-.03	.17	-.04	.27
Alpha Index	.01	.10	.04	.11	-.13	.16	.05	.31
Alpha Frequencies	-.01	.20	-.04	.14	.10	.19	.12	.34
Abnormalities	.04	.07	-.13	.19	.07	.17	-.09	.26

any one of the three measures tends to be associated with a lower rating on the other two. It is possible, therefore, for these two sets of measures to locate an individual within a distribution of individuals, various segments of which may be called types. When the relations of these two sets of measures (Table 25C) are investigated, it is apparent that the types which they may distinguish are of entirely different orders. As have appeared in another report, these two methods of psycho-physical classification are also entirely unrelated to a third, respiration. If they all measure "type," then there must be various kinds of type.[57]

The next step in the analysis related to the study of the tests for their value in differentiating the washouts from the parent population. The results are shown in Table 26. An examination of the tables makes it clear that the washouts do not differ from the parent population with respect to the distribution of their scores on any one of the somatotype variables used alone. This conclusion rests upon the fact that none of the P-values is lower than 0.23 (for mesomorphy). Even this lowest P-value means that, as many as 23 times out of 100, as large a difference as that between washouts and all pilots would occur by chance. Essentially the same conclusion is warranted when pilots whose aptitude is in doubt but who have not been grounded (board appearances) are compared with the total population. With the exception of the somatotype for ectomorphy, the lowest P-value is 0.18, which means that at least 18 times out of 100, chance would produce a disparity as large as that between the board appearances and total population distributions. Such disparity cannot be considered reliable.

The somatotype for ectomorphy has a P-value of 0.06. This value is also below the level of statistical significance employed in this study indicating that such a difference between washouts and all pilots would occur by chance 6 times out of 100. Although this finding is positive, it can be only suggestive since it could have occurred due to chance differences in the data.

SUMMARY

As indicated at the beginning of the study, the design of this investigation involved the administration of a large number of psychological and physiological tests to approximately 1,000 cadets and officers so as to determine whether certain of these tests would differentiate the successful pilots from the washouts, or those who failed the flight training course. It was assumed that if such tests were found, they might be given at the time of initial selection in order to prevent much time and effort from being wasted on men who were eventually dropped for poor aptitude. At this time, it seems in order to present a general recapitulation of the findings in all of the measures employed in the study.

Two measures of reliability have been used as criteria for differentiating successful pilots from poor ones; i.e., washouts and board appearances;

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[57]Detailed statistical analysis of the data will appear in subsequent reports.

TABLE 26

THE PROBABILITY THAT WASHOUTS FOR APTITUDE AND PILOTS WHO HAVE HAD BOARD APPEARANCES ARE NOT SIGNIFICANTLY DIFFERENT FROM ALL PILOTS IN THEIR SCORES ON ELECTROENCEPHALOGRAM AND SOMATOTYPE MEASURES

Test	N of Parent Population	N of Washouts	N of Board Appearances	P-Value: Washouts vs. Parent Population	P-Value: Board Appearances vs. Parent Population
Electroencephalogram:					
Voltage	355	34	34	.93	.97
Abnormalities	355	34	34	.30	.30
Alpha Index	355	34	34	.43	.58
Alpha Frequencies	355	34	34	.88	.53
Somatotype:					
Endomorphy	364	34	35	.73	.18
Mesomorphy	364	34	35	.23	.66
Ectomorphy	364	34	35	.75	.06
Dysplasia	231	18	27	.804	.82

TABLE 27

TESTS IN WHICH CRITICAL RATIO IS GREATER THAN 2.0 IN COMPARING DIFFERENCES BETWEEN THE MEANS FOR GOOD AND POOR PILOTS

Test	Critical Ratios: Successes vs. Washouts, Part I	Critical Ratios: Successes vs. Washouts, Part II	Critical Ratios: Good Pilots vs. Washouts plus Board Appearances, Part I	Critical Ratios: Good Pilots vs. Washouts plus Board Appearances, Part II
Mental Ability (Otis)	5.02	2.34	2.95	2.82
Mechanical Aptitude (Minnesota)	—	—	2.35	—
Athletic Achievement (Thorndike-Kelley)	2.19	*	—	*
Eye-Hand Coordination	2.36	3.22	2.27	2.79
Two-Hand Coordination	5.46	3.21	3.46	2.39
Washburn Serial Action Test	4.47	3.27	6.64	4.25
Dotting (McDougall)	—	—	2.31	—
Continuous Reaction (Cattell):				
Part A (the slow strip)	2.68	—	3.25	—
Part B (the fast strip)	2.53	—	3.37	—
Parts A and B	2.46	—	3.50	—
Ophthalmograph (fixations/line)	2.52	*	—	*
Tidal Air/Body Surface	—	—	—	2.20
Vital Capacity	2.75	—	—	—
Vital Capacity/Body Surface	2.79	—	—	—
Tilt Table:				
Systolic Blood Pressure	2.60	—	—	—
Pulse Rate	—	2.28	—	—
Smallest Pulse Pressure	2.28	—	—	—
Cold Pressor:				
Greatest Systolic Change	—	*	2.00	*
Greatest Diastolic Change	2.40	*	—	*
Electroencephalogram:				
Voltage	—	—	2.55	—
Abnormalities	—	—	—	2.56
Body Build (Somatotyping):				
Endomorphy	2.19	—	2.08	2.61
Ectomorphy	2.07	—	—	2.52

*Test was not given.
**Test was not scored.

namely, the critical ratios between the means and the P-value for the chi-square between the two distributions. In Table 27 all of the critical ratios greater than 2.0 in comparing the difference between the mean for good and poor pilots have been summarized. Although a critical ratio of 3.0 or at least 2.5, has been the accepted level of significance throughout this investigation, it was thought advisable to include those between 2.0 and 3.0 in this table in order to bring out any further trends in the data. An inspection of the table indicates that the psychological tests proved to be of greatest value in terms of the objectives set up for this study.

The results obtained with the P-value of the chi-square test between the distributions of the successful pilots, washouts, and board appearances are shown in Table 28. All values less than 0.02 have been included. Here again, it is obvious that the psychological tests differentiated the good and poor pilots far more successfully than the physiological ones.

TABLE 28

TESTS IN WHICH P-VALUE IS LESS THAN .02 IN COMPARING THE DISTRIBUTION OF GOOD AND POOR PILOTS

Test	P-Values			
	Successes vs. Washouts		Good Pilots vs. Washouts plus Board Appearances	
	Part I	Part II	Part I	Part II
Mental Ability (Otis)	-	.01	-	-
Eye-Hand Coordination	-	.01	-	.01
Two-Hand Coordination	.01	.01	.01	-
Keehburn Serial Action Test	.01	.02	.01	.01
Continuous Reaction (Cattell):				
Part A (the slow strip)	-	*	.01	*
Body Build (Somatotyping):				
Ectomorphy	-	-	.01	-

*Test was not scored in Part II

CONCLUSIONS

The following tentative conclusions may be drawn from the results of this exploratory investigation:

1. The psychological tests as a group differentiated the successful pilots from the poor pilots (washouts and board appearances) in a more significant way than the physiological ones. Judged in terms of the critical ratios between the means and the P-value between the two distributions, the following four psychological tests showed satisfactory results: (a) Otis Test of Mental Ability, (b) Eye-Hand Coordination Test, (c) Two-Hand Coordination

Test, (d) Washburn Serial Action Test. For these four tests the criteria were upheld in practically all of the various groupings: when the successes were compared with the washouts and when the good pilots were compared with the washouts plus board appearances, as well as in both Parts I and II. It may be tentatively concluded, therefore, that the above three or four tests could be used in a battery at the time of original selection to eliminate a certain percentage of the pilots at the lower end of the distribution from enlistment or from continuing in flight training. This is especially true if they are used as a battery with the advantage of compensation.

2. The physiological tests, in contrast to the psychological ones, were not successful in differentiating the good pilots from the poor pilots. Of all the physiological measures employed, Vital Capacity, or Vital Capacity / Body Surface, and Time to Smallest Pulse Pressure after being tilted on the Tilt Table are the best possibilities. It should be remembered, however, that the results on these variables are suggestive of trends only, and that the differences between criterion groups employed in this study fell below the accepted levels of significance, i.e., below a critical ratio of 3.00 or a P-value of 0.01. Further analysis of the data indicated that the low reliability for the physiological measures may have been due to the fact that the tests were not truly representative of the individual and should have been repeated more often and over a longer period of time to obtain a higher reliability for each measure. It is also possible that certain experimental irregularities, e.g., changes in temperature between Parts I and II of the study gave rise to a sampling error in the collection of the data on these variables. It must be concluded, therefore, that before any of these physiological measures can be recommended for use in the selection of pilots, refinement, standardization, and cross-validation would have to be carried out with the most promising tests.

3. Although many of the physiological and psychological measures employed in this study did not differentiate between the successful pilots and the poor ones, it is important to observe the general trend of the results. Almost without exception, the mean scores for the board appearances, or for those who failed a large number of flight checks, were below the means of pilots who successfully completed the course. Furthermore, the means for the washouts were generally below those of the board appearances. Thus, washouts and those having board appearances, tended to make poorer (but not significantly poorer) scores on all of the tests. Such trends as these should not be overlooked in the design of future research on the construction of test batteries for the selection of aircraft pilots.

4. Although it has been suggested that certain of the tests employed in this study, e.g., audiokonia, electrocardiography, and electroencephalography, might still prove of value in the handling of individual clinical cases which come before the flight surgeon the results of this investigation indicate that they are valueless (in their present form) for the prediction of success in flight training.

5. Definite conclusions concerning the relationship between somatotype and flight training success cannot be drawn from the results of this investigation largely because the group of subjects was predominantly of one body type, viz., mesomorphic.

RECOMMENDATIONS FOR FUTURE RESEARCH

On the basis of the experience gained in carrying out the investigation described in this report the following general outcomes of value for future research in the development of batteries for the selection of naval aviators may be mentioned:

1. Criteria. The examination of flight records, more particularly of flight jackets, suggests the need for a thorough analysis and revision of training records with a view to providing more acceptable and detailed criteria of pilot proficiency.

2. Psychological Tests. Results of the investigation indicate that the following tests warrant further evaluation as selection instruments: (1) Otis Test of Mental Ability (or an equivalent test of general intelligence); (2) the Two-Hand Coordination Test; (3) the Washburn Serial Action Test; and (4) the Eye-Hand Coordination Test.[58]

3. Physiological Tests. The experimental findings point particularly to the need for investigating further and improving the reliability of physiological tests before they can be seriously considered for use in objective batteries for the selection of pilots.[59] The questionable reliability of the physiological tests, combined with the generally negative findings of the relationship between test results and criteria of flight performance, prevents the formulation of positive recommendations pointing to the use of such tests in selection programs.

4. General. The findings of this investigation point to the need for using heterogeneous groups, consisting of applicants for flight training, in the definitive exploration of the validity of psychological tests, physiological tests and other selection techniques, in accordance with the usual practices in test evaluation.

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[58] Editor's Note. Selection test batteries now employed by the C.A.A., the Army Air Force and the Naval Bureau of Aeronautics all include one or more of these tests, with the exception of the Eye-Hand Coordination Test. Independent validation studies carried out by the services and by the National Research Council Committee on Selection and Training of Aircraft Pilots during the last three years have provided evidence that these tests can be used effectively in pilot selection.

[59] Editor's Note. An example of a detailed analysis in an attempt to determine the most reliable measures obtainable from one of the physiological tests is described in: Franzen, Raymond and Blaine, Louisa. Op. cit.

APPENDIX A

1 SAMPLE OF PERSONAL AND MEDICAL HISTORY FORM

2 RESULTS FROM QUESTIONNAIRES RELATING TO PERSONAL AND MEDICAL HISTORY

PERSONAL AND MEDICAL HISTORY FORM

(1) NAME:_____ CLASS #_____
(Last) (First) (Middle)

Age:_____ Height:_____ Weight:_____

(2) FAMILY HISTORY

Maternal grandmother: Age_____ Died ___ ago_____ Cause of death (if known)_____
Maternal grandfather: Age_____ Died ___ ago_____ Cause of death (if known)_____
Paternal grandmother: Age_____ Died ___ ago_____ Cause of death (if known)_____
Paternal grandfather: Age_____ Died ___ ago_____ Cause of death (if known)_____

Brothers: Approx. ages:_____
Sisters: Approx. ages:_____
Wife:_____
Children:_____

Indicate relation of blood relatives who have had:
Cancer_____
Tuberculosis_____
Heart Trouble_____
Kidney Trouble_____
Insanity_____
Diabetes_____
Allergy (hay fever, asthma, hives, unusual reaction to certain foods)_____
Nervous Breakdown_____
What other illnesses are frequent in your family?_____

In any member of your family now in the hospital or sick at home?_____
If so, give details:_____

Father: Age:_____ Died at age:_____ Cause of death:_____
Serious illnesses_____
Education_____ Occupation_____
How successful?_____
Characteristics (For instance, is he phlegmatic or irritable? Strict or lenient? Genial or serious? Easy going or tense? Steady or emotional?)_____

Mother: Age:_____ Died at age:_____ Cause of death:_____
Serious illnesses_____
Education_____
Occupation_____
Is she well adjusted?_____ What civic and social activities does she participate in?_____
Characteristics_____

What is your family origin? (English, French, etc.)_____
Father's family_____
Mother's family_____
What religions are represented in your immediate family? (Protestant? Catholic? Jewish? Other? Indicate if more than one)_____

State your family's (including your fiancee's) reaction to your present course_
Approve or object?_____
Pleased, worried, or both?_____
Further explanation:_____

(3) PERSONAL HISTORY

Have you ever fainted?_____If so, give date and details_____

Have you ever been "knocked out"?_____If so, give date, details and length of time "out"_____

Have you ever had a head-injury?_____

Check any of the following diseases or conditions you have had and give age:

CONTAGIOUS DISEASES
- Scarlet Fever
- Diphtheria
- Typhoid Fever
- Malaria
- Sleeping Sickness
- Syphillis
- Gonorrhoea

LUNGS
- Pain in chest
- Chronic cough and expectoration
- Bloody expectoration
- Hemorrhage from lungs
- Tuberculosis
- Pneumonia
- Asthma

HEART AND CIRCULATION
- Any heart disease?
- Rheumatic fever
- Rheumatism
- Leaky valves
- Growing pains (arms and legs)
- Nose bleeds
- Undue shortness of breath on exertion
- Palpitation of heart
- Irregular pulse
- Dizziness upon rising or exercise
- Swollen ankles (other than sprain or accidents)
- Hemorrhage

GASTRO-INTESTINAL
- Appendicitis
- Nausea or vomiting associated with low abdominal pain
- Indigestion
- Constipation
- Food Poisoning
- Hemorrhages from mouth
- Hemorrhages from bowels
- Ulcers of stomach
- Ulcers of intestines
- Hernia (rupture)

GENITO-URINARY
- Frequent urination
- Painful urination
- Wakefulness at night to empty bladder
- Sores on genitals
- Infection of genitals with discharge of pus
- Hemorrhage from genitals

NEURO-PSYCHIATRIC
- Headache-recurrent and severe
- Sleeplessness
- Neuralgia
- Sleepwalking episodes
- Disturbing nightmares
- Bedwetting (after 6 yrs. of age)
- Disturbance of teachability
- Sudden blank periods in memory

NEURO-PSYCHIATRIC (cont.)

Nervousness (without apparent reason)
Nail biting
Speech defect
Recurrent worries
Moody ups and downs (What do you think causes them?)
Have you ever been severely upset by the death of a friend, broken love affair, or disappointment at school, college, or elsewhere?

EAR, NOSE, AND THROAT

Colds. How often?_____
Persistent sore throat
Severe sinus trouble
Discharge from ears
Mastoiditis
Hay Fever
Sores in mouth
Sores in corner of mouth or lips

Discuss any of the above conditions that need further explanation:_____

Have you ever had any unusual laboratory tests or X-ray examinations made in your case?_____ If so, give date and details_____

From a health observation standpoint, is there any organ or region of your body to which you would like a physician to devote special and searching attention? What?_____

What are your most pressing worries at present?_____

Do you ever have a feeling of tightness or pressure in your head? Or peculiar feelings elsewhere, such as numbness or difficulty in moving? Where and under what conditions?_____

Do you retain any of the usual fear associated with flying?_____ If so, is it due to (1) dangers of learning to fly, (2) fear of combat, (3) uncertainty about passing flight checks (check which)
What worries you most about it?_____

Have you had any serious accidents, broken bones, dislocations, or surgical operations?_____ Give dates and details_____

How much tobacco do you use daily?_____

What drugs or medicines do you take regularly (if any)_____
How much alcohol do you use? Beer_____ per week. Cocktails_____ per week. Whiskey_____ per week. How often?_____
Do you think you are more or less susceptible to alcohol than most people?_____

How often do you consult your dentist?_____ When last?_____

Eating Habit:

Do you skip meals?____ Which ones?____ How often?____ Did you skip meals at college?____ At home?____ If so, explain why_____

Do any foods disagree with you?_____

Check whether you take the following foods, "usually," "occasionally," "never." If occasionally, say in the space below how many times a week.

	Usually	Occasionally	Never
Milk			
Cream			
Butter			
Meat			
Chicken			
Fish			
Eggs			
Cheese			

	Usually	Occasionally	Never
Oranges or juice			
Tomatoes or juice			
Fresh fruits			
Whole grain cereals			
Oatmeal			
Cold cereal (which)			
Coarse grain bread (other than white)			

	Usually	Occasionally	Never
Carrots			
Cabbage			
Cauliflower			
Beans			
Peas			
Greens			
Potatoes			
Salads			

How does the mess compare with your food in college? Check. Better_____ About same?_____ Worse?_____ If worse, describe in what way_____

What is your opinion as to the quality of the food? Check. Good_____ Average_____ Poor_____ What is your opinion as to the preparation of the food? Check. Well prepared_____ Average_____ Poor_____ If "average" or "poor," write clearly and concisely your criticism and recommendation_____

(4) ENVIRONMENT

Reared by whom until college_____ Where - Population_____

Birth order:_____ child out of_____ children in family.

Economic condition:_____

Discipline (harsh? mild? variable?)_____

Was there particular emphasis on certain principles?_____ What ones?_____

Home conflicts: Between who (& other members of family)_____
Broken Home_____
Reaction to, or opinion of, home training (for instance, did parents try to run your life too much? Do you believe it could have been better or was it O.K.?)_____

Religious Conflicts: Parents_____ Family_____

(5) EDUCATION

Grammar School, name and location_____
Years_____ Standing (1st, 2nd, 3rd, or 4th quarter of class)_____
Failures_____

High School, name and location_____
Years_____ Standing (1st, 2nd, 3rd, or 4th quarter of class)_____
Subjects in which you were good_____
Subjects in which you were weak_____
Failures_____
Extra curricular activities (athletics, class offices, publications, etc.)_____

U. S. Naval Academy: Year graduated_____ Class standing_____

Colleges: Name_____ Years_____
Name_____ Years_____
Name_____ Years_____
Class standing_____ Degree_____ Year_____ Age_____
What was your major in college?_____
What did you plan as a career when you entered college?_____
Did you change your major? If so, why?_____
Extra curricular activities_____
In what subjects were you especially good?_____
In what subjects were you especially weak?_____
What subjects did you fail?_____
Reasons_____
Approximately how much of your support in college did you contribute?_____
Training other than college_____
Have you any dependents now?_____
What jobs have you had in college, summers, and since college? Indicate ones you liked and disliked (why) and those you did well and poorly (why)_____

(6) VOCATIONAL

What professions have you seriously considered? When and for how long?

What led you to make aviation your profession? (Give your own discussion below, then check off appropriate comments below)

How long have you been considering it seriously?
Did you build model planes? What sorts of planes? At what age?

How many of the following suggestions influenced your decision to take up aviation Give the numbers in the spaces below and explain details further. Add additional explanations of your own.

1. Felt the emergency called for all possible pilots?
2. Since you'd probably be called to some type of military service, you would prefer to be in aviation?
3. Because you felt that you could make some particular contributions to aviation as instructor, pilot, specialist, or in some other function? Specify.
4. (a) Because of what you read in magazines or elsewhere?
   (b) Because of moving pictures?
5. Because you considered naval aviation the best training for later commercial work, as air line manager, test pilot, etc.?
6. Considered yourself especially qualified for military flying and hence likely to do well in it?
7. To prove to yourself or others that you could make good in flying?
8. Attracted by salary?
9. To develop valuable habits, such as self-discipline or judgment? What particular ones?
10. To get away from other surroundings and worries? What were they?
11. Because, though undecided at first, you were persuaded or encouraged by others? Why doubtful at first? Who persuaded you?
12. Fascinated by the sensations of flight from first experience?
13. Mainly for sport? Or adventure?
14. Just suddenly decided?
15. Drifted into it without thinking much about it?
16. Always figured on going into flying?
17. Had interests related to flying? Mechanical, engineering, medical, etc., that led you into it? Other interests.
18. Felt it was an important and promising profession in itself?

What hobbies have you had? (Including reading and types of material read). Give ages of various interests.

Previous flying experience (Including Elimination Base, C.A.A., private and miscellaneous):

Location and Approx. Dates	Hours of Control or Under Instruction	Type of Plane	Number in Class	Number Dropped From Training	Your Approximate standing

State roughly the amount of passenger time you have had:

Commercial airlines_____
Private planes_____
Military planes_____

At what age did you first go up in an airplane?_____ What flight maneuvers or routine proceedings have seemed easiest for you to learn?_____

What ones have seemed particularly difficult?_____

What have your instructors considered to be your strong points?_____

Your weak points?_____

If you had your choice, what particular type of aviation would you prefer? (Check)

Fighting carrier_____ Military instructor_____
Patrol_____ Commercial instructor_____
Scouting and observation_____ Photography_____
Test piloting_____ Gunnery_____

Have you had any flying accidents?_____ Have you had any near accidents?_____
Describe these and state their effect upon you_____

Signature:_____

TABLE A-1

RESULTS FROM QUESTIONNAIRE RELATING TO PERSONAL AND MEDICAL HISTORY
(Family History)

	SUCCESSES				WASHOUTS			
	Part I (N=436)		Part II (N=417)		Part I (N=39)		Part II (N=113)	
	N	Per Cent**	N	Per Cent**	N	Per Cent**	N	Per Cent**
Maternal Grandmother:								
Mean Age (living)	73.1*	32.1	73.2*	31.3	78.1*	43.7	75.4*	35.5
Mean Age at death	65.4*	67.9	74.9*	68.7	67.8*	56.3	69.3*	64.5
Maternal Grandfather:								
Mean Age (living)	77.5*	26.9	77.1*	17.1	73.5*	19.4	77.2*	17.1
Mean Age at death	66.4*	73.1	74.6*	82.9	68.0*	80.6	68.1*	82.9
Paternal Grandmother:								
Mean Age (living)	77.3*	31.4	77.4*	21.6	81.1*	21.9	76.2*	34.7
Mean Age at death	74.6*	68.6	74.5*	78.4	68.9*	78.1	68.8*	65.3
Paternal Grandfather:								
Mean Age (living)	81.9*	14.5	77.5*	17.3	78.9*	21.9	76.8*	16.7
Mean Age at death	74.6*	85.5	74.6*	82.7	68.3*	78.1	70.2*	83.3
Incidence of Diseases among Blood Relatives:								
Cancer	33	15.3	76	18.3	10	25.6	15	13.3
Tuberculosis	28	11.9	24	5.8	4	10.3	11	9.7
Heart Trouble	57	24.3	90	21.6	9	23.1	25	22.1
Kidney Trouble	23	9.8	44	10.5	5	12.8	13	11.5
Insanity	8	3.4	3	0.7	0	0.0	1	0.9
Diabetes	18	7.7	36	8.6	4	10.3	11	9.7
Allergy	21	8.9	28	6.7	3	7.7	8	7.1
Nervous Breakdown	26	11.1	25	6.0	3	7.7	8	7.1
Other (Ser. Illnesses)	11	4.7	13	3.1	4	10.3	15	13.3
Father:								
Mean Age (living)	57.3*	80.2	53.1*	89.6	55.2*	79.5	59.7*	75.2
Mean Age at death	54.6*	19.8	47.8*	10.4	56.0*	20.5	52.9*	24.8
Serious Illnesses	42	17.9	86	20.6	7	17.9	20	17.7
Education:								
Grammar	48	25.4	91	26.1	11	42.3	26	33.3
High School	68	37.6	132	37.9	9	34.6	25	32.1
College	50	27.6	77	22.1	3	11.5	19	24.4
College Plus	17	9.4	48	13.8	3	11.5	8	10.3
Mother:								
Mean Age (living)	52.4*	90.6	49.3*	92.1	51.3*	92.3	52.0*	86.1
Mean Age at death	42.5*	9.4	42.4*	7.9	36.7*	7.7	49.0*	13.9
Serious Illnesses	63	26.8	66	15.8	10	25.6	16	14.2
Education:								
Grammar	32	16.7	64	19.3	10	34.5	26	32.9
High School	103	53.6	188	56.8	14	48.3	36	45.6
College	57	29.7	72	21.8	5	17.2	17	21.5
College Plus	0	0.0	7	2.1	0	0.0	0	0.0

TABLE A-1 (continued)

	SUCCESSES				WASHOUTS			
	Part I (N=236)		Part II (N=417)		Part I (N=39)		Part II (N=113)	
	N	Per Cent**	N	Per Cent**	N	Per Cent**	N	Per Cent**
Occupation:								
Housewife	129	74.6	305	38.3	29	85.3	78	81.3
Teacher	18	10.4	17	6.0	1	2.9	7	7.3
Nurse	4	2.3	5	1.6	2	5.9	3	3.1
Other	22	12.7	18	5.2	2	5.9	8	8.3
Outside Activities:								
Church	63	26.1	122	24.9	12	22.2	44	27.0
Social	57	23.7	156	31.8	20	37.0	36	22.0
Civic	38	15.8	129	26.2	4	7.4	25	15.3
Misc.	62	25.7	50	10.2	5	9.2	16	9.8
None	21	8.7	34	6.9	13	24.1	42	25.8
Family Origin: Number of Racial and National Groups represented:								
1	55	23.3	93	23.3	13	41.0	37	33.6
2	89	38.0	171	42.8	15	38.5	35	31.6
3	65	27.8	93	23.3	7	17.9	26	23.6
4	19	8.1	32	8.0	1	2.6	12	10.9
5	3	1.3	9	2.3	0	0.0	0	0.0
6	3	1.3	1	0.2	0	0.0	0	0.0
Religion of Immediate Family:								
Protestant	159	68.0	298	74.0	22	56.4	72	64.9
Catholic	39	16.7	62	15.4	15	38.5	24	21.6
Jewish	5	1.4	5	1.2	2	5.1	3	2.7
Mixed	33	14.1	37	9.2	0	0.0	12	10.8
Family's Reaction to Present Course:								
Approve	170	64.2	328	55.5	31	55.3	87	45.8
Object	38	11.5	62	10.5	6	10.7	22	11.6
Pleased	59	18.8	99	16.7	8	14.3	43	22.6
Worried	26	8.3	72	12.2	9	16.1	19	10.0
Pleased and Worried	23	7.3	30	5.1	2	3.6	19	10.0

*Mean of total answers.
**Percentage is calculated in terms of total number of answers to each question.

TABLE A-2

RESULTS FROM QUESTIONNAIRE RELATING TO PERSONAL AND MEDICAL HISTORY
(Personal and Medical History)

	SUCCESSES				WASHOUTS			
	Part I (N=235)		Part II (N=417)		Part I (N=39)		Part II (N=113	
	N	Per Cent**	N	Per Cent**	N	Per Cent**	N	Per Cent**
Have fainted	31	13.4	40	8.8	6	15.4	11	9.7
Have been "knocked out"	89	38.9	185	40.7	10	27.8	40	35.4
Have had head injury	36	22.9	61	16.2	5	18.5	13	25.5
Illnesses Experienced:								
Contagious Diseases	38	16.2	99	23.8	11	28.2	35	31.0
Lungs	70	29.8	50	12.0	11	28.2	14	12.4
Heart and Circulation	59	25.1	52	12.5	17	43.6	27	23.9
Ear, Nose, and Throat	150	63.8	153	36.7	24	61.5	64	56.6
Gastro-Intestinal	149	63.4	92	22.1	23	59.0	29	25.7
Genito-Urinary	27	11.5	44	10.5	4	10.3	9	8.0
Neuro-Psychiatric	107	45.5	125	30.0	20	51.3	49	43.4
None	20	8.5	103	24.8	1	2.6	21	18.6
Total with One or More	215	91.5	314	75.2	38	97.4	92	81.4
Serious Accidents, Broken Bones, Dislocations or Surgical Operations:	138	58.8	265	63.6	23	59.0	56	49.6
Tobacco Consumption (per day):								
None	80	34.4	162	39.6	14	35.9	36	32.7
Up to 1/2 package	64	27.5	124	30.4	10	25.6	28	25.4
1/2 to one package	86	36.9	98	24.0	14	35.9	43	39.1
Over one package	3	1.3	25	6.1	1	2.6	3	2.7
Do you Drink Alcoholic Beverages?								
Yes	209	89.0	334	80.1	31	81.6	98	88.3
No	26	11.0	83	19.9	7	18.4	13	11.7
Tolerance to Alcohol:								
More than Average	48	33.4	67	27.6	15	57.7	21	36.2
Average	70	48.6	115	47.4	6	23.1	28	48.3
Less than Average	26	18.0	61	25.1	5	19.2	9	15.5
Consultation with Dentist (per year):								
Less than Once	19	8.2	45	11.0	3	7.7	15	13.9
Once	71	30.5	151	36.9	9	23.1	32	29.6
Twice	122	52.3	172	41.9	24	61.5	55	50.9
More than Twice	21	9.0	41	10.0	3	7.7	6	5.5
Never	0	0.0	1	0.2	0	0.0	0	0.0
Do any Foods Disagree with You?								
Yes	43	31.8	52	19.4	5	20.0	10	23.3
No	92	68.2	216	80.6	20	80.0	33	76.7

**Percentage is calculated in terms of total number of answers to each question.

TABLE [illegible]-3

RESULTS FROM QUESTIONNAIRE RELATING TO PERSONAL AND MEDICAL HISTORY
(Environmental Influences)

	SUCCESSES				WASHOUTS			
	Part I (N-238)		Part II (N-417)		Part I (N-39)		Part II (N-113)	
	N	Per Cent**	N	Per Cent**	N	Per Cent**	N	Per Cent**
Reared by Whom:								
Parents	182	82.3	243	77.1	32	84.2	86	78.2
Father	4	1.8	17	5.4	1	2.6	1	0.9
Mother	22	10.0	24	7.6	3	7.9	12	10.9
Other	13	5.9	31	9.8	2	5.3	11	10.0
Where Reared by Area:								
New England	16	7.2	31	7.9	5	13.5	7	6.0
Middle Atlantic	28	12.6	24	6.1	7	18.9	18	15.4
South Atlantic	27	12.2	31	7.9	7	18.9	12	10.3
North Central	85	37.8	158	40.1	9	24.3	43	36.7
South Central	22	9.8	56	14.2	4	10.8	15	12.8
Mountain	9	4.0	26	6.6	2	5.4	7	6.0
Pacific	36	16.0	63	16.0	3	8.1	15	12.8
Foreign	2	0.9	5	1.3	0	0.0	0	0.0
Population of Home City:								
1,000 or less	20	9.4	58	15.1	5	12.8	21	18.4
1,000 - 5,000	26	12.3	71	18.6	9	23.1	22	19.3
5,000 - 10,000	23	10.8	38	9.9	4	10.2	13	11.4
10,000 - 20,000	26	12.3	42	11.0	4	10.2	14	12.3
20,000 - 100,000	38	17.9	67	17.5	7	17.9	15	13.1
100,000 - 1,000,000	60	28.3	89	23.2	10	25.6	21	18.4
1,000,000 and over	19	9.0	18	4.7	7	17.9	8	7.0
Total under 20,000	95	44.9	209	54.6	22	56.4	70	61.4
Birth Order:								
First	88	38.1	162	40.1	11	29.7	43	40.2
Second	81	35.1	112	27.7	15	40.5	28	26.2
Third	29	12.5	59	14.6	3	8.1	13	12.1
Fourth	14	6.1	26	6.4	3	8.1	10	9.3
Fifth	10	4.3	20	5.0	1	2.7	4	3.7
Sixth	2	0.9	12	3.0	3	8.1	5	4.7
More than Sixth	7	3.0	13	3.2	1	2.7	4	3.7
Number of Siblings (Including self):								
1 - 2	78	33.1	127	33.5	10	34.5	39	34.5
3 - 4	104	45.2	148	41.3	5	17.2	35	31.0
5 - 6	28	12.2	47	13.1	7	24.1	21	18.6
7 - 8	19	8.3	28	7.3	5	17.2	13	11.5
More than 8	5	1.8	10	2.8	2	6.9	5	4.5
Mean Number of Brothers	1.2*		1.4*		2.2*		1.5*	
Mean Number of Sisters	1.3*		1.4*		1.5*		0.9*	

TABLE A-3 (continued)

	SUCCESSES				WASHOUTS			
	Part I (N=235)		Part II (N=217)		Part I (N=39)		Part II (N=37)	
	N	Per Cent**	N	Per Cent**	N	Per Cent**	N	Per Cent**
Economic Conditions at Home:								
Very Good	14	5.9	4	2.0	3	8.1	3	8.1
Good	92	41.4	114	54.4	12	32.4	38	102.7
Average	105	47.3	201	51.6	17	45.9	53	143.2
Poor	8	3.6	44	17.3	5	13.5	6	16.2
Very Poor	3	1.4	3	0.8	0	0.0	4	10.8
Discipline:								
Mild	33	15.2	78	18.7	6	16.2	40	108.1
Variable	19	8.8	41	10.6	4	10.8	22	59.5
Strict	68	31.4	92	23.9	16	43.2	22	59.5
Good	51	23.6	81	21.0	4	10.8	15	40.5
Average	46	21.2	100	25.9	7	18.9	10	27.0
Home Conflicts:								
None	184	85.5	306	92.7	28	77.8	64	172.9
Parents	28	13.0	51	13.8	6	16.7	15	40.5
Others	3	1.4	13	3.5	2	5.6	2	5.4
Broken Home:								
Yes	24	10.7	37	9.9	1	2.9	16	43.2
No	200	89.3	338	90.0	33	97.1	70	189.2
Reaction to Home Training:								
Very Good	81	37.5	115	31.5	11	29.7	30	81.1
Satisfactory-Good	113	52.3	211	58.6	23	62.2	55	148.6
Poor-Improvable	22	10.2	36	10.0	3	8.1	11	29.7
Religious Conflicts:								
Yes	10	4.7	16	5.4	0	0.0	2	5.4
No	201	95.3	341	96.6	38	100.0	81	218.9

*Mean of total answers.

**Percentage is calculated in terms of total number of answers to each question.

TABLE A-4

RESULTS FROM QUESTIONNAIRE RELATING TO PERSONAL AND MEDICAL HISTORY
(Education)

	SUCCESSES				WASHOUTS			
	Part I (N-235)		Part II (N-417)		Part I (N-39)		Part II (N-113)	
HIGH SCHOOL:	N	Per Cent**	N	Per Cent**	N	Per Cent**	N	Per Cent**
Location by Area:								
New England	18	7.9	32	7.9	5	13.2	6	5.4
Middle Atlantic	28	12.3	26	6.4	7	18.4	16	14.3
South Atlantic	30	13.2	33	8.1	7	18.4	12	10.7
North Central	79	34.5	159	39.1	10	26.3	42	37.5
South Central	25	11.0	53	13.0	4	10.5	14	12.5
Mountain	9	4.0	32	7.9	1	2.6	7	6.2
Pacific	39	17.2	71	17.5	4	10.5	15	13.4
Number of Years:								
1 - 2	2	0.9	4	1.0	1	2.6	5	4.9
3 - 4	210	89.5	255	87.0	34	89.5	96	90.4
Over 4	22	9.4	49	12.0	3	7.9	5	4.9
Scholastic Standing:								
First Fourth	126	55.5	164	58.2	20	51.3	39	39.4
Second Fourth	62	27.3	47	16.7	10	25.6	42	42.4
Third Fourth	23	10.1	40	14.2	3	7.7	8	8.1
Last Fourth	2	0.9	2	0.7	1	2.6	2	2.0
Average	4	1.8	14	5.0	1	2.6	7	7.1
Good	10	4.4	15	5.3	4	10.2	1	1.0
Subjects Failed:								
None	179	80.0	329	78.6	30	76.9	72	72.7
Nat., Sci. & Math.	3	1.3	22	5.3	3	7.7	10	10.1
Foreign Language	21	9.4	27	6.4	5	12.8	11	11.1
Social Science	3	1.3	11	2.6	0	0.0	1	1.0
Biological Science	0	0.0	0	0.0	0	0.0	1	1.0
English	5	2.2	16	4.3	0	0.0	3	3.0
Miscellaneous	13	5.8	12	2.9	1	2.6	1	1.0
Extra Curricular Activities:								
Publications	53	10.0	83	9.8	9	8.5	21	7.0
Athletics	263	47.9	379	44.2	61	57.6	185	61.3
Social	33	6.5	50	5.8	7	6.6	22	7.3
Managerial	83	16.7	166	13.2	14	13.2	33	11.0
Dramatics; Mus. Organiz.	55	10.4	110	12.9	10	9.4	30	9.9
Miscellaneous	36	6.8	54	6.3	3	2.8	9	3.0
None	11	2.1	25	2.9	2	1.9	2	0.7
COLLEGE:								
Degree Received:								
U. S. Naval Academy	53	33.1	3	0.4	2	8.0	2	3.0
Associate in Arts	2	1.2	15	5.5	1	4.0	2	3.0
Associate in Science	2	1.2	1	0.4	0	0.0	1	1.5
Bachelor of Arts	35	21.9	99	36.4	6	24.0	19	28.8
Bachelor of Science	50	31.3	105	38.6	7	28.0	35	53.1
Other	12	7.5	41	15.1	4	16.0	6	9.1
Not Specified	6	3.7	10	3.7	5	20.0	1	1.5

TABLE A-4 (continued)

	SUCCESSES				WASHOUTS			
	Part I (N=225)		Part II (N=417)		Part I (N=39)		Part II (N=113)	
	N	Per Cent**	N	Per Cent**	N	Per Cent**	N	Per Cent**
Age Graduated:								
19 - 20	10	7.0	33	12.9	4	16.0	5	7.5
21 - 22	61	43.0	127	49.4	11	44.0	22	33.3
23 - 24	62	43.6	75	29.2	8	32.0	33	50.0
25 - 26	9	6.3	22	8.6	2	8.0	6	9.1
Major:								
Nat. Sci. & Math.	95	47.5	173	41.3	15	42.9	32	34.4
Foreign Language	1	0.5	4	1.0	1	2.9	2	2.2
English and Speech	10	5.0	23	5.5	3	8.6	1	1.1
Social Science	38	19.0	83	19.9	4	11.4	30	32.6
Biological Science	18	9.0	42	10.1	4	11.4	9	9.7
Business	30	15.0	64	15.4	6	17.1	9	9.7
Education	8	4.0	27	6.5	2	5.7	10	10.8
Extra Curricular Activities:								
Publications	26	6.2	35	4.4	3	10.3	15	7.0
Athletics	194	46.0	312	39.4	38	43.7	99	45.8
Social	62	14.7	154	19.5	17	19.6	54	25.0
Managerial	42	10.0	84	10.6	8	9.2	19	8.8
Dramatics, Pub. Organiz.	28	6.7	82	10.3	3	3.4	15	7.0
Miscellaneous	52	12.3	87	11.0	7	8.0	11	5.1
None	17	4.4	38	4.8	5	5.7	3	1.4
Subjects Failed:								
None	126	64.6	147	52.4	15	44.1	44	46.8
Nat. Sci. & Math.	37	19.0	60	21.4	12	35.3	17	18.1
Foreign Language	10	5.1	16	5.7	5	14.7	9	9.6
English and Speech	12	6.2	18	6.4	0	0.0	8	8.5
Social Science	4	2.0	20	7.1	2	5.9	8	8.5
Biological Science	1	0.5	7	2.5	0	0.0	4	4.3
Business	5	2.6	11	3.9	0	0.0	4	4.3
Miscellaneous	0	0.0	4	1.4	0	0.0	0	0.0
Contribution to College Expenses:								
0 - 19%	68	36.5	98	16.3	6	17.1	5	16.7
20 - 39%	36	11.4	71	17.3	5	14.3	5	16.7
40 - 59%	36	15.4	75	18.3	3	8.6	3	10.0
60 - 79%	19	8.4	58	14.2	2	5.7	3	10.0
80 - 100%	63	28.4	101	24.3	19	54.3	6	20.0
Miscellaneous	11	4.8	37	9.0	0	0.0	8	26.7

**Percentage is calculated [illegible] number of answers to each question.

TABLE A-5

RESULTS FROM QUESTIONNAIRE RELATING TO PERSONAL AND MEDICAL HISTORY
(Vocational and Aeronautical Interests)

	SUCCESSES				WASHOUTS			
	Part I (N=235)		Part II (N=417)		Part I (N=39)		Part II (N=115)	
	N	Per Cent**	N	Per Cent**	N	Per Cent**	N	Per Cent**
Reasons for Entering Aviation:								
Felt Especially Qualified	8	3.4	7	1.2	21	24.7	40	8.8
Adventure and Salary	58	17.3	49	8.1	7	8.2	73	16.1
Career and Allied Interests	129	53.6	169	28.4	30	35.3	133	29.3
Escape or Second Choice	8	3.4	12	2.0	1	1.2	40	8.8
Previous Experience	13	5.9	124	20.6	3	3.6	18	4.0
Long Interest	43	12.9	109	18.1	8	9.4	44	9.7
Influenced by Others	24	7.2	70	11.6	6	7.1	35	7.7
Miscellaneous	51	15.3	74	12.2	9	10.6	71	15.7
Did you Build Model Planes?								
Yes	119	51.1	199	33.8	18	47.4	65	60.7
No	114	48.9	165	45.2	20	52.6	42	39.3
Age of First Flight:								
6 - 9	1	1.5	0	0.0	0	0.0	0	0.0
10 - 13	15	22.4	18	24.0	1	20.0	7	11.3
14 - 17	20	29.9	13	17.4	1	10.0	17	27.4
18 - 21	17	25.4	24	32.0	4	40.0	14	22.6
22 - 26	14	20.9	17	22.7	4	40.0	24	38.7
Have you had Flying Accidents?								
Yes	15	15.2	11	6.5	1	8.2	9	8.3
No	53	53.5	148	87.7	8	50.0	81	75.0
Near	31	31.4	78	37.9	7	43.8	18	16.7

**Percentage is calculated in terms of total number of answers to each question.

HIGHEST CRITICAL RATIOS OF PERCENTAGE DIFFERENCES BETWEEN WASHOUTS AND SUCCESSES OF VARIOUS ELEMENTS OF THE MEDICAL HISTORY QUESTIONNAIRE

	Part I	Part II
Family History:		
Maternal Grandfather (living)	+2.6*	
Serious Illnesses among Blood Relations other than those listed		-2.4
Fathers: Living		+3.4
Not living		-3.4
Grammar School only	-3.1	
Mothers: College education	-1.9	
Interest in civic activities		+2.8
No outside interests	-1.8	-4.3
Family Origin: No group represented		-2.2
Personal and Medical History:		
Illnesses experienced:		
Heart and circulation	-2.3	-2.8
Neuro-psychiatric		-2.6
Environmental Influences:		
Number of Siblings: 3-4	+4.1	+2.0
Discipline at Home: Mild		-2.7
Good	+2.5	+2.9
Average		+4.8
Education:		
High School: Not Fourth in Class		+3.6
Interest in Athletics		-3.5
College: Failed no Subjects	+2.5	
Vocational and Avocational Interests:		
Reasons for entering aviation:		
Felt especially qualified	-3.2	-3.1
Previous experience		+6.0
Age of 1st Flight: 19-18 years	-2.2	+3.6
22-26	-2.3	-3.2

* + indicates a higher percentage of Successes.
- indicates a higher percentage of Washouts.

[illegible] ATHLETIC ACHIEVEMENT TEST

NAME IN FULL
Last Name [illegible] Middle Name

Date_____
School_____

Answer the following questions
(approximately)

1. How many yards can you swim?
2. How many yards (approximately) can you ride your bike?
3. Can you sail a boat?
4. How many miles (approximately) have you run?
5. Can you run a mile?
6. How many miles (approximately) have you hit?
7. Can you ride a motorcycle?
8. How many miles (approximately) have you ridden?
9. Can you drive a motor car?
10. How many miles (approximately) have you driven?
11. Can you ride a horse?
12. How many miles (approximately) have you ridden?
13. Can you play tennis?
14. How many hours (approximately) have you played?
15. Can you play any musical instrument? What is the instrument?
16. How many hours (approximately) have you played it?
17. Do you know any children under [illegible] What is the grade?
18. How much more [illegible] do you do?

Examine the [illegible] games, sports and amusements listed below. Think which ones you like best to do and mark them L. Think which ones you like next best and mark them g. Think which ones you like least; mark them n. If there are any others that you like or at least mark them ng. If there are any others that you know enough about to be able you to decide how well you like to play each one, write them in at the end.

19. Play [illegible]
20. Boxing
21. Run a motor [illegible]
22. Sail a [illegible]
23. Play cards
24. Play chess
25. Play baseball
26. See the movies
27. Dancing
28. Walking
29. Play football
30. [illegible] horse race
31. Ride a motor cycle
32. Drive a motor car
33. Play some musical instrument
34. Listen to music
35. Reading
36. Shooting
37. Swimming
38. Play tennis
39. Talk with friends
40. Go to the theatre
41. Wrestling

SQUADRON ONE

STUDENT _____ CLASS _____ INSTRUCTOR _____

		DUAL										SOLO			EXTRA TIME			SOLO RX			PRIMARY SOLO							20-Hr.			EXTRA - TIME				20 Hr. RX			EXTRA TIME				20 Hr. RX			TOTALS		SUB-TOTALS	
		1	2	3	4	5	6	7	8	9	10	X	X	X	1	2	3	X	X	X	4	7	10	13	16	20	X	X	X	1	2	3	4	X	X	X	1	2	3	4	X	X	X	No.	%	No.	%
Perception and Control of Plane's Position	Nose Low (Fast) Land. excluded																																													
	Nose high (Slow) Land. excluded																																													
	Right Wing Low																																													
	Left Wing Low																																													
	Veer / Yaw } Swerve																																													
	Slip																																													
	Skid																																													
	Fast or Hot Landing																																													
	Dropped or Stalled High																																													
Approach or Level	* Too High																																													
	Too Low																																													
COORDINATION OF CONTROLS	Rough At Controls																																													
	Careless At Controls																																													
	Tense at Controls																																													
	Overcontrol																																													
	Undercontrol																																													
	Slow In Response																																													
	Slow in Emergency																																													
MENTAL PERFORMANCE	Emotional Instability																																													
	Indifferent Attitude																																													
	Slow Assimilating Instructions																																													
	Poor Judgment																																													
	Violation																																													
	Near Accident																																													
	Accident																																													
SPECIFIC MANEUVERS	R-C Turns																																													
	Spirals																																													
	Precision Landings																																													
	Pylons																																													
	Wingovers																																													
	Stunts																																													
	Small Fields																																													
	Spins																																													
	TOTALS																																													

A—Approach
S—Slip
U—Turn
T—Taxi
O—Take-off
C—Climb
F—Flight
G—Glide
L—Land
V– Check

SQUADRON ONE

STUDENT _____ CLASS _____ INSTRUCTOR _____

SQUADRON TWO

		ADVANCED SOLO			SOLO 25 Hr.			EXTRA TIME				25 Hr. EX			EXTRA TIME				25 Hr. EX			Formation		Selection	FORM.		Final Instr.		FINAL			EXTRA TIME				FINAL EX			EXTRA TIME				FINAL EX			SOLO					SOLO			TOTALS	
		25	26	31	X	X	X	1	2	3	4	X	X	X	1	2	3	4	X	X	X	1	2	1	X	X	1	2	X	X	X	1	2	3	4	X	X	X	1	2	3	4	X	X	X	1	2	3	4	5	X	X	X	No.	Hr.
Perception and Control of Plane's Position	Nose Low (Fast) Land. excluded																																																				
	Nose high (Slow) Land. excluded																																																			
	Right Wing Low																																																			
	Left Wing Low																																																			
	Veer / Yaw / Swerve																																																			
	Slip																																																			
	Skid																																																			
	Fast or Hot Landing																																																			
	Dropped or Stalled High																																																			
Approach or Level	Too High																																																			
	Too Low																																																			
Coordination of Controls	Rough At Controls																																																			
	Careless At Controls																																																			
	Tense at Controls																																																			
	Overcontrol																																																			
	Undercontrol																																																			
	Slow In Response																																																			
	Slow in Emergency																																																			
Mental Performance	Emotional Instability																																																			
	Indifferent Attitude																																																			
	Slow Assimilating Instruction																																																			
	Poor Judgment																																																			
	Violation																																																			
	Near Accident																																																			
	Accident																																																			
Stalling Maneuvers	S-C Turns																																																			
	Spirals																																																			
	Precision Landings																																																			
	Pylons																																																			
	Wingovers																																																			
	Spirals																																																			
	Small Fields																																																			
	Spins																																																			
	TOTALS																																																			

A—Approach
S—Slip
T—Turn
T—Taxi
O—Take-off
C—Climb
F—Flight
G—Glide
L—Land
V—Check

APPENDIX D

CAUSES OF ELIMINATIONS BASED ON DATA OBTAINED FROM INTERVIEWS WITH CADETS PRIOR TO THEIR BEING DROPPED FROM FLIGHT TRAINING

APPENDIX I

CAUSES OF ELIMINATIONS BASED ON DATA OBTAINED FROM INTERVIEWS WITH CADETS PRIOR TO THEIR BEING DROPPED FROM FLIGHT TRAINING

Each pilot who was dropped from flight training was interviewed at the research laboratory by a physician with psychiatric training. The interview occurred prior to his appearance before the Commandant's Advisory Board. Thus, any significant findings in the examination were made available to the Board. The purpose of the interview was to uncover the primary causes underlying each cadet's failure, or his reasons for withdrawal. In the table below the primary causes of elimination, according to these 195 interviews, are presented. About half of the cadets failed because of lack of proficiency in ground school or flight training. Another large percentage (approximately 25%) did not lack intelligence but apparently they were tense and nervous in flight. The remaining 25% appeared to fail because of a variety of reasons, as seen in the table. It is interesting that 8, or 4.1%, developed psychoneurotic symptoms (conversion hysteria) which disappeared when they were definitely eliminated.

Caution must be observed in the interpretation of these data because of the method by which they were obtained. In the first place, it is recognized that the data are based on the opinions of the cadets themselves as to the causes of their failure or on the interpretations of the examining physician. In many cases the cadets may not have been aware of the real

PRIMARY CAUSES OF ELIMINATIONS ACCORDING TO INTERVIEWS
(Total = 195)

Causes	N	Percentage of Total
Lack of Ability to Learn:		
(a) Flight instruction	85	43.6%
(b) Ground courses	16	8.2
Nervous Tension; fear of flying	47	24.1
Poor Coordination; rough on controls	25	12.8
Poor Judgment under Stress	17	8.7
Emotional Instability	10	5.1
Poor Judgment of Speed and Distance	6	3.1
Own Request	35	17.9
Lack of Motivation	9	4.6
Discipline	10	5.1
Irresponsibility	8	4.1
Physical Disqualification	11	5.6
Airsickness	7	3.6
Conversion Symptoms (headache, ulcer pain, dizziness, or insomnia)	8	4.1

causes of their difficulties or they may have concealed them. It should also be kept in mind that reliable psychiatric analyses may require many hours of examination to reveal basic difficulties. Little can be said of these find-

ings from the point of view of selection since it is not known how many of the students who passed the course had the same difficulties. It is of interest, however, that the lack of ability to learn and poor motor coordination were two of the prominent expressed causes of failure, and this corresponds with results in the tests relating to mental ability and motor control.

APPENDIX E

SAMPLE DISTRIBUTIONS OF TEST SCORES

1. OTIS TEST OF MENTAL ABILITY
2. TWO-HAND COORDINATION TEST
3. MASHBURN CEREAL ACTION TEST
4. VITAL CAPACITY / BODY SURFACE
5. SCHNEIDER INDEX OF NEUROCIRCULATORY FITNESS
6. TILT TABLE: SYSTOLIC PULSE PRESSURE

TABLE E-1

PARTS I AND II

FREQUENCY DISTRIBUTION OF VAT MECH TEST
PENSACOLA AVIATION CADETS (CLASSES 147-165)

Raw Score**	Successes f	Washouts f	% Successes at and below each score interval	% Washouts at and below each score interval
78-74	2	-	100	100
73-69	12	2	100	100
68-64	28	3	98	99
63-59	75	7	94	96
58-54	112	15	82	91
53-49	113	22	65	80
48-44	105	23	48	63
43-39	123	19	32	46
38-34	50	16	13	32
33-29	27	5	5	20
28-24	8	8	1	9
23-19	-	3	-	3
18-14	-	1	-	*

	N	Mean	Sigma	C.R.$_m$	C.R.$_\sigma$	P-value (χ^2)
SUCCESSES	554	43.6 (±.4)	10.7 (±.3)	4.56	1.27	<.01
WASHOUTS	134	41.7 (±1.0)	11.5 (±.7)			

* less than 1%.

** A high raw score indicates superior performance.

TABLE B-2

PARTS I AND II

FREQUENCY DISTRIBUTION OF THE CIVIL WEST PENSACOLA AVIATION CADETS (CLASSES 147-165)

Raw Score**	Good Pilots f	Washouts plus Board Appearances f	% Good Pilots at and below each score interval	% Washouts plus Board Appearance at and below each score int
78-74	1	1	100	100
73-69	10	3	100	100
68-64	24	7	98	98
63-59	66	16	93	96
58-54	100	27	81	89
53-49	96	39	62	73
48-44	87	41	45	63
43-39	92	50	28	47
38-34	35	31	13	27
33-29	20	22	7	14
28-24	6	10	1	5
23-19	*	2	*	2
18-14	*	1	*	*

	N	Mean	Sigma	Gallup	Colwell	P-value (χ^2)
SUCCESSES	557	49.2 (±0.4)	9.6 (±0.3)			
				5.13	3.11	<.01
WASHOUTS	251	44.9 (±0.7)	10.6 (±0.5)			

* Less than 1%

** A high raw score indicates superior performance.

TABLE B-3

PARTS I AND II

FREQUENCY DISTRIBUTION OF THE TWO-HAND COORDINATION TEST
PENSACOLA AVIATION CADETS (CLASSES 147-165)

Standard Score**	Successes f	Washouts f	% Successes at and below each score interval	% Washouts at and below each score interval
+3.0	1	-	100	100
+2.5	7	-	100	100
+2.0	20	-	99	100
+1.5	39	6	96	100
+1.0	83	10	90	95
+0.5	135	16	77	88
0	131	14	57	75
-0.5	115	32	37	64
-1.0	73	23	19	39
-1.5	28	18	8	21
-2.0	10	6	4	7
-2.5	12	2	2	2
-3.0	4	1	*	*

	N	Mean	Sigma	C.R.$_m$	C.R.$_\sigma$	P value (χ^2)
SUCCESSES	658	+0.05 (±0.04)	1.00 (±0.03)	5.51	0.57	<.01
WASHOUTS	128	-0.46 (±0.08)	0.96 (±0.06)			

* Less than 1%.

** Raw scores are based on the mean of 4 trials; positive standard scores equal low raw scores and indicate superior performance.

TABLE E-4

PARTS I AND II

FREQUENCY DISTRIBUTION OF THE TWO-HAND COORDINATION TEST
PENSACOLA AVIATION CADETS (CLASSES 147-153)

Standard Score**	Good Pilots f	Washouts plus Board Appearances f	% Good Pilots at and below each score interval	% Washouts pl Board Appearan at and below each score inte
+3.0	1	-	100	100
+2.5	7	-	100	100
+2.0	17	3	99	100
+1.5	37	8	96	99
+1.0	70	23	89	95
+0.5	119	32	77	84
0	117	28	56	69
-0.5	95	52	36	56
-1.0	63	33	19	31
-1.5	23	23	8	16
-2.0	10	6	4	5
-2.5	10	4	2	2
-3.0	4	1	*	*

	N	Mean	Sigma	C.R.$_m$	C.R.$_\sigma$	P-value (χ^2)
SUCCESSES	573	+0.07 (±.04)	1.01 (±0.03)	4.79	0.67	<.01
WASHOUTS	213	-0.29 (±.07)	0.97 (±0.05)			

* less than 1%.

** Raw scores are based on the mean of 4 trials; positive standard scores equal low raw scores and indicate superior performance.

TABLE B-5

PARTS I AND II

FREQUENCY DISTRIBUTION OF THE WASHBURN SERIAL ACTION TEST
PENSACOLA AVIATION CADETS (CLASSES 147-165)

Standard Score**	Good Pilots f	Washouts plus Board Appearances f	% Good Pilots at and below each score interval	% Washouts plus Board Appearances at and below each score interval
+2.0	5	-	100	100
+1.5	24	-	99	100
+1.0	90	11	95	100
+0.5	165	33	81	94
0	157	52	55	77
-0.5	88	42	30	50
-1.0	61	27	15	28
-1.5	21	14	6	14
-2.0	11	5	2	7
-2.5	3	2	*	4
-3.0	-	3	*	3
-3.5	1	-	*	2
-4.0	-	2	-	2
-4.5	-	1	-	*

	N	Mean	Sigma	C.R.$_m$	C.R.$_\sigma$	P-value (χ^2)
SUCCESSES	626	+0.08 (±0.03)	0.69 (±0.02)	6.12	2.80	<.01
WASHOUTS	192	-0.41 (±0.07)	0.94 (±0.05)			

* less than 1%.

** Raw score is expressed in minutes; a positive standard score equals a low raw score and indicates superior performance.

TABLE B-8

PARTS I AND II

FREQUENCY DISTRIBUTION OF THE WASHBURN SERIAL ACTION TEST
PENSACOLA AVIATION CADETS (CLASSES 147-165)

Standard Score**	Successes f	Washouts f	% Successes at and below each score interval	% Washouts at and below each score interval
+2.0	5	-	100	100
+1.5	24	-	99	100
+1.0	95	6	96	100
+0.5	182	16	82	95
0	177	32	56	81
-0.5	105	25	31	53
-1.0	68	20	16	32
-1.5	25	10	6	15
-2.0	14	2	3	6
-2.5	3	2	*	4
-3.0	1	1	*	3
-3.5	1	-	*	2
-4.0	1	1	*	2
-4.5	-	1	-	*

	N	Mean	Sigma	C.R.$_m$	C.R.$_\sigma$	P-value (χ^2)
SUCCESSES	701	+0.04 (±0.03)	0.82 (±0.02)	5.67	1.67	<.01
WASHOUTS	116	-0.47 (±0.09)	0.92 (±0.06)			

* less than 1%.

** Raw score is expressed in minutes; a positive standard score equals a low raw score and indicates superior performance.

TABLE 6-7

PANELS I AND II

FREQUENCY DISTRIBUTION OF THE VITAL CAPACITY/BODY SURFACE PENSACOLA AVIATION CADETS (CLASSES 147-165)

Raw Score**	Successes f	Washouts	% Successes at and below each score interval	% Washouts at and below each score interval
3918-3759	1	-	100	100
3758-3599	2	-	100	100
3598-3439	14	1	100	100
3438-3279	17	3	98	99
3278-3119	70	7	95	97
3118-2959	73	8	85	92
2958-2799	134	12	75	86
2798-2639	138	16	56	70
2638-2479	128	17	37	43
2478-2319	75	12	18	29
2318-2159	32	9	8	12
2158-1999	15	7	3	6
1998-1839	6	2	1	*
1838-1679	2	*	*	-
1678-1519	1	-	*	-

	N	Mean	Sigma	C.R.$_m$	C.R.$_\sigma$	P-value (χ^2)
SUCCESSES	70[illegible]	2743.8 (±11.9)	316.8 (±8.4)	2.81	0.47	.02
WASHOUTS	13[illegible]	2662.3 (±26.5)	307.2 (±18.7)			

* Less than 1%.

** Vital Capacity is expressed in cubic centimeters and was determined when the subject was in a sitting position; a high score indicates superior performance.

TABLE E-3

PARTS I AND II

FREQUENCY DISTRIBUTION OF THE VITAL CAPACITY/BODY SURFACE
PENSACOLA AVIATION CADETS (CLASSES 147-165)

Raw Score**	Good Pilots f	Washouts plus Board Appearances f	% Good Pilots at and below each score interval	% Washouts plus Board Appearances at and below each score int.
3918-3759	1	-	100	100
3758-3599	2	-	100	100
3598-3439	10	5	99	100
3438-3279	14	6	98	98
3278-3119	59	16	96	95
3118-2959	63	23	86	88
2958-2799	117	39	75	81
2798-2639	114	60	53	64
2638-2479	107	46	37	40
2478-2319	69	26	19	23
2318-2159	27	14	7	12
2158-1999	10	12	3	7
1998-1839	5	2	1	*
1838-1679	2	-	*	-
1678-1519	1		*	

	N	Mean	Sigma	C.R.m	C.R.σ	P value (t)
SUCCESSES	601	2754.9 (±13.3)	326.4 (±9.4)	3.92	1.09	.05
WASHOUTS	242	2906.2 (±21.1)	328.0 (±14.9)			

* Less than 1%

** Vital Capacity is expressed in cubic centimeters and was determined when the subject was in a sitting position; a high score indicates superior performance

TABLE E-9

PART I

FREQUENCY DISTRIBUTION OF THE SCHNEIDER INDEX
PENSACOLA AVIATION CADETS (CLASSES 147-151)

Raw Score**	Successes f	Washouts f	% Successes at and below each score interval	% Washouts at and below each score interval
20 to 18	1	-	100	100
17 to 15	33	3	100	100
14 to 12	82	9	90	92
11 to 9	135	15	55	68
8 to 6	39	4	25	27
5 to 3	36	6	13	16
2 to 0	8	-	3	-
-1 to -3	-	-	*	-
-4 to -6	1	-	*	-

	N	Mean	Sigma	C.R. .01	C.R. .05	P value (χ^2)
SUCCESSES	335	9.6 (±0.2)	3.7 (±0.1)	0.90	0.50	.95
WASHOUTS	37	9.[illegible] (±0.[illegible])	3.4 (±0.[illegible])			

* less than 1%.

** A high score indicates superior performance.

TABLE E-10

PART I

FREQUENCY DISTRIBUTION OF THE SCHNEIDER INDEX (CLASSES 147-151)

Raw Score**	Good Pilots f	Washouts plus Board Appearances f	% Good Pilots at and below each score interval	% Washouts plus Board Appearances at and below each score interval
+20 to +18	1	-	100	100
+17 to +15	30	6	100	100
+14 to +12	77	14	90	91
+11 to +9	115	35	64	71
+8 to +6	36	7	26	20
+5 to +3	36	6	15	10
+2 to 0	7	1	3	1
+1 to -1	-	-	*	-
-4 to -6	1	-	*	-

	N	Mean	Sigma	C.R.$_m$	C.R.$_\sigma$	P-value (χ^2)
SUCCESSES	303	.6 (±0.2)	3.8 (±0.2)	0.25	1.90	.16
WASHOUTS	69	.7 (±0.4)	3.2 (±0.3)			

* less than 1%.

** A high score indicates superior performance.

TABLE E-11

PARTS I AND II

FREQUENCY DISTRIBUTION OF THE TILT TABLE TEST: SMALLEST PULSE PRESSURE
PENSACOLA AVIATION CADETS (CLASSES 147-165)

Raw Score**	Successes f	Washouts f	% Successes at and below each score interval	% Washouts at and below each score interval
0- 3	8	-	100	100
4- 7	47	3	99	98
8-11	42	7	90	92
12-15	79	15	82	80
16-19	132	25	68	60
20-23	99	28	43	37
24-27	45	19	25	22
28-31	39	13	17	11
32-35	30	10	9	3
36-39	12	1	4	2
40-43	5	1	2	2
44-47	4	1	*	*
48-51	-	-	-	*
52-55	-	-	-	*
56-59	-	1	-	*

	N	Mean	Sigma	C.R.$_{\sigma_M}$	C.R.$_{\sigma}$	P-value (χ^2)
SUCCESSES	542	19.5 (±0.4)	8.6 (±0.3)	3.44	0.77	.02
WASHOUTS	124	22.4 (±0.7)	8.2 (±0.5)			

* less than 1%

** Smallest pulse pressure is the smallest difference between systolic and diastolic blood pressure during the interval between tilt and untilt.

TABLE B-12

PARTS I AND II

FREQUENCY DISTRIBUTION OF THE KELP TABLE TEST: SMALLEST PULSE PRESSURE
PENSACOLA AVIATION CADETS (CLASSES 147-165)

Raw Score**	Good Pilots f	Washouts plus Board Appearances f	% Good Pilots at and below each score interval	% Washouts plus Board Appearances at and below each score interval
0- 3	8	-	100	100
4- 7	41	9	98	100
8-11	34	15	88	96
12-15	63	31	81	90
16-19	106	51	66	77
20-23	76	51	41	56
24-27	33	31	23	35
28-31	28	24	15	22
32-35	22	18	9	12
36-39	8	5	3	4
40-43	3	3	2	2
44-47	4	1	*	*
48-51	-	-	-	*
52-55	-	-	-	*
56-59	-	1	-	*

	N	Mean	Sigma	C.R.$_{\bar{x}}$	C.R.$_{\sigma}$	P-value (χ^2)
SUCCESSES	426	19.1 (±0.4)	8.6 (±0.3)	4.04	0.83	4.01
WASHOUTS	240	21.3 (±0.5)	8.2 (±0.4)			

* less than 1%.

** Smallest pulse pressure is the smallest difference between systolic and diastolic blood pressure during the interval between tilt and untilt.

APPENDIX F

INTERCORRELATIONS OF PHYSIOLOGICAL AND CENTRIFUGAL ACCELERATION VARIABLES

LIST OF PHYSIOLOGICAL VARIABLES CORRELATED WITH EVERY OTHER IN RELATION TO SUSCEPTIBILITY TO CENTRIFUGAL ACCELERATION

The numbers given to each of the variables in the following list are to be used in reading Tables F-1 and F-2 of this Appendix

Variable No. — Variables

1. Age
2. Total Flying Hours
3. Schneider Index
4. Cold Pressor and Carotid Sinus:
   a. Systolic Blood Pressure (sitting)
   b. Diastolic Blood Pressure (sitting)
   c. Maximum Systolic Blood Pressure (Cold Pressor Test)
   d. Maximum Diastolic Blood Pressure (Cold Pressor Test)
   e. Pulse Pressure (sitting)
   f. Pulse Pressure (difference between sitting pulse pressure and pulse pressure at time of Cold Pressor Test)
   g. Pulse Pressure (difference between sitting pulse pressure and pulse pressure at time of pressure on both carotid arteries)
   h. Systolic Blood Pressure at time of pressure on both carotid arteries
   i. Diastolic Blood Pressure at time of pressure on both carotid arteries
5. Somatotype:
   a. Endomorphy
   b. Mesomorphy
   c. Ectomorphy
6. Height
7. Weight
8. Height/$\sqrt[3]{\text{Weight}}$
9. Nipple-ear Distance (in cm.)
10. Tilt Table:
   a. Systolic Blood Pressure (lying)
   b. Diastolic Blood Pressure (lying)
   c. Pulse Pressure (lying)
   d. Pulse Rate (resting)
   e. Minimum Systolic Blood Pressure (tilted at 65° angle)
   f. Minimum Diastolic Blood Pressure (tilted at 65° angle)
   g. Maximum Pulse Rate (tilted at 65° angle)
   h. Maximum Pulse Rate Change (before and during tilt)
   i. Maximum Blood Pressure Change (before and during tilt)
   j. Smallest Pulse Pressure (during tilt)
   k. Time of Smallest Pulse Pressure (during tilt)
11. Stated Tolerance to Centrifugal Acceleration
12. Theoretical Tolerance based on Blood Pressure (sitting)
13. Theoretical Tolerance based on Minimum Blood Pressure (on tilt)

TABLE F-2

MEANS AND STANDARD DEVIATIONS

Variable	Mean	Sigma
1	57.6	1.8
2	1356.6	443.0
3	11.9	3.1
4a	114.4	10.4
4b	79.0	3.4
4c	129.4	10.8
4d	95.2	11.7
4e	36.2	9.8
4f	0.7	33.6
4g	15.6	32.9
4h	114.4	2.0
4i	87.7	2.3
5a	3	--
5b	4	--
5c	2	--
6	70.3	2.3
7	167.9	17.0
8	12.8	0.7
9	35.3	1.9
10a	120.3	3.8
10b	75.9	2.2
10c	45.3	3.6
10d	72.3	20.1
10e	205.6	3.4
10f	88.0	3.8
10g	108.5	10.4
10h	32.0	3.4
10i	30.6	2.0
10j	15.1	3.5
10k	12.4	3.2
11	6.4	1.6
12	4.4	0.4
13	4.0	0.4

TAB[illegible]

CORRELATION OF EACH PHYSIOLOGICAL VARIABLE WITH EVERY OTHER [illegible] RELATION TO SUSCEPTIBILITY TO CENTRIFUGAL ACCELERATION (g)

(N [illegible])

Variable	AGE 1	HRS. 2	SCH. IND. 3	COLD PRESSOR AND CAROTID SINUS 4a	4b	4c	4d	4e	4f	4g	4h	4i	SOMATOTYPE VARIABLES 5a	5b	5c	H[illegible] 6	WEIGHT [illegible] 7	8	UNP. EAR TEST 9	TILT TABLE VARIABLES 10a	10b	10c	10d	10e	10f	10g	10h	10i	10j	10k	TOLERANCE VARIABLES 11	12	13
1	---	63	22	20	23	18	04	01	-09	13	10	23	[illegible]	26	-20	[illegible]	[illegible]	-26	-19	-07	17	-22	45	03	22	-11	-30	-18	-20	33	-04	16	07
2		---	13	17	30	18	29	-08	10	25	-08	24	06	[illegible]	-15	-05	[illegible]	-19	02	-02	10	-11	24	-07	21	-20	-08	-03	-34	06	-16	16	-13
3			---	10	10	03	12	02	09	-09	06	-05	10	-10	[illegible]	06	[illegible]	-06	-02	02	10	-07	-24	20	10	44	-28	-23	16	-33	-05	01	16
4a				---	47	75	23	65	18	33	54	35	-03	[illegible]	-11	[illegible]	[illegible]	-19	09	45	19	21	21	41	26	07	-25	18	13	43	07	65	28
4b					---	30	35	-36	-20	-03	22	51	22	25	-32	[illegible]	[illegible]	-38	05	15	47	-29	25	22	36	17	-41	-23	-08	-26	16	26	-03
4c						---	48	53	13	25	35	17	14	[illegible]	[illegible]	[illegible]	[illegible]	-33	-03	42	25	13	22	34	24	-04	-18	23	-07	27	001	60	28
4d							---	-06	68	11	02	19	33	10	[illegible]	[illegible]	[illegible]	-43	-14	14	33	-18	07	13	15	06	-14	-12	-09	02	-04	33	[illegible]
4e								---	35	37	38	-07	-21	-04	[illegible]	[illegible]	[illegible]	12	04	34	-20	48	-05	24	-09	-07	08	17	18	66	-06	44	15
4f									---	27	05	03	09	-07	[illegible]	[illegible]	[illegible]	-11	-09	09	-005	08	-12	04	-12	02	07	-02	06	41	-10	23	07
4g										---	-25	45	-11	-05	20	07	[illegible]	15	18	-03	-01	-01	21	-19	-04	-14	-04	11	-32	03	-18	19	-26
4h											---	48	04	20	-17	[illegible]	[illegible]	-15	-07	36	01	29	11	42	14	02	-13	11	34	92	25	41	38
4i												---	10	19	[illegible]	[illegible]	[illegible]	-10	07	08	18	-11	33	05	19	-06	-25	-10	-13	44	13	24	01
5a													---	-06	[illegible]	[illegible]	[illegible]	-70	-16	-10	02	-23	-12	02	23	13	-10	-21	-02	-38	16	12	11
5b														---	-55	[illegible]	[illegible]	-46	[illegible]	[illegible]	19	-19	29	18	52	-01	-25	-10	-11	05	03	11	24
5c															---	57	[illegible]	68	[illegible]	-06	-28	-20	-03	-19	-33	-13	25	15	03	88	-12	-27	-32
6																---	[illegible]	45	51	-08	-02	-05	-26	-15	-14	04	25	02	-09	70	-21	-28	-39
7																	---	[illegible]	[illegible]	-04	28	-29	-12	04	28	15	-07	-21	-10	-12	-03	09	-03
8																		---	37	-07	-30	21	-11	-18	-38	-12	28	20	-01	88	-17	-33	-55
9																			---	08	-09	16	-10	-03	-18	-09	22	10	-05	71	-35	-53	-58
10a																				---	37	53	03	66	34	03	-03	41	26	-30	12	39	50
10b																					---	-60	16	33	57	14	-27	-35	-36	-99	02	22	32
10c																						---	-12	27	-23	-11	22	70	46	65	09	13	14
10d																							---	-003	22	-56	-33	05	-25	16	08	23	04
10e																								---	58	39	-43	03	53	05	27	32	85
10f																									---	04	-28	04	-24	-39	16	36	58
10g																										---	-55	-44	51	-31	20	08	36
10h																											---	41	-28	-09	-23	-26	08
10i																												---	-19	52	-05	23	-02
10j																													---	-01	32	-001	44
10k																														---	-25	-42	-29
11																															---	18	41
12																																---	55
13																																	---