NOT FOR PUBLICATION



# AN HISTORICAL INTRODUCTION

# TO

# AVIATION PSYCHOLOGY

Prepared

By

National Research Council
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Training of Aircraft Pilots
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LETTER OF TRANSMITTAL

October 14, 1942

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

Dear Dr. Brimhall:

Inquiries received by the Committee on Selection and Training of Aircraft Pilots indicate that there is a need for an integrated survey of the history of Aviation Psychology. You have undoubtedly been made aware of this need by the reception accorded to the ABSTRACTS OF AVIATION PSYCHOLOGY published by the Civil Aeronautics Administration in 1941.

The attached material represents such an historical introduction to Aviation Psychology. It was written primarily to become Chapter I of the text on Aviation Psychology, which is under preparation by the Committee on Selection and Training of Aircraft Pilots. However, because of the present situation, this Chapter is now transmitted to you by the Committee with the recommendation that, pending the publication of the text, this material be issued separately.

Cordially yours,

/s/ Morris S. Viteles

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

Attachment.
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# AN HISTORICAL INTRODUCTION

# TO

# AVIATION PSYCHOLOGY


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# F O R E W O R D

During the First World War psychologists in belligerent countries were called upon to help in the selection and maintenance of aviation personnel. They made important beginnings in a field which was completely novel to them before the War. Almost immediately after the Armistice was signed, however, research was virtually abandoned, to be resumed only shortly before the start of the present conflict.

During the peak of research activity, a large amount of literature was produced. This has been supplemented by reports on a few studies conducted during the past decade. While investigators have been able to locate pertinent publications in bibliographies (115, 117), more particularly in the Abstracts of Aviation Psychology (116), recently published by the Civil Aeronautics Administration, there has been no recent integrated survey of work in the field of aviation psychology.

The material which follows is intended to supply such a review of the application of psychology in aviation prior to the present World War. Its chief purpose is to provide those interested in aeronautical research with information which will enable them to capitalize upon the fruitful experience of early investigators, and to avoid the mistakes made in earlier psychological studies. This is, then, essentially an historical introduction* to aviation psychology, ultimately intended, in fact, to become Chapter I of a text on AVIATION PSYCHOLOGY which is being prepared by the National Research Council Committee on Selection and Training of Aircraft Pilots.

Since emphasis in this presentation is upon history, there can be only brief critical references to the studies reported. It is hoped that reference to a study, or to a piece of equipment, will not be accepted as

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* Prepared with the editorial assistance of N. L. Munn, Vanderbilt University

even presumptive evidence that the results of the study or the apparatus described can be usefully employed. Much of the early work is not useful because many investigations were done hastily, under the pressure of war, and without the advantages of statistical methodology and other aids now available to psychologists. The applicability of even substantiated findings is limited because of the great changes which have taken place in the nature of the aircraft and in the tasks of personnel employed in current military operations.

In general, the reader who is informed on present day practices and standards in applied psychology will find much to question in the methods and outcomes of the studies reported in this historical introduction to aviation psychology. There was, for example, an almost complete neglect of job analysis as a basis for determining accurately the tasks performed by pilots. Tests were frequently used merely because they appeared to be reasonable measures for aptitude in flying and without adequate experimental justification of the test instruments. Research was conducted in the laboratory, rather than in the cockpit of the plane, and as a result nothing was made available in the way of objective measures of pilot performance in the air. Practically no attention was paid to psychological aspects of training. Important problems of maintenance, including those of tension during flight; fatigue; effects of motion sickness, and so on, were almost completely neglected.

In spite of such deficiencies, even the critical reader will find in earlier research certain useful apparatus and significant findings. For example, acceptable evidence is presented that simple reaction time tests

and the well known Barany chair, widely used during the first World War because they seemed reasonable, were actually without value in selecting pilots. Such findings have prevented a waste of effort in research during the present World War. Promising measures of complex reaction were developed and these are finding a place in batteries of selection and classification tests now in use. The investigator will discover a few promising leads with respect to research techniques, as well as equipment, which can facilitate his efforts to make psychology useful in the selection, training and maintenance of pilots. Above all, this historical introduction provides a background and perspective for the evaluation of current research in aviation psychology.

# 1. INTRODUCTION

Aviation psychology originated during the first World War. The lead in applying psychology to aviation was taken in France and Italy, where minimum physical standards for acceptance of candidates for flight training were formulated in 1916 and 1917 respectively. Before the first World War ended, most of the belligerents were using psychological as well as physical procedures in the acceptance and rejection of aviation candidates.

Attention centered upon psychological methods in selection for the following reasons: (1) Despite selection on the basis of rigid physical examinations a large percentage of the trainees washed out.[1] (2) Among those who graduated from flight training courses some required up to twice as much training as others.[2] (3) Even after graduation there were large

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[1] Gilchrist (47, pp.401-403) reported that, of 100 qualified pilots, student pilots, balloon officers, etc., who had been grounded, 67 were disqualified because of psychological defects such as "loss of nerve", poor memory, inadequate powers of concentration, poor judgment, and temper. Hennon (52, pp. 103-104) mentions a report by the Director of Military Aeronautics in which it was stated that 980 students had been commissioned and 400 dropped for inability to fly. As recently as 1931, Longacre (62, pp. 431-435) reported that 57% of Army Air Corps Cadets accepted for training were eliminated before graduation. Tenseness and apprehension were said to be important factors underlying this elimination.

[2] Hennon (52, p. 104) points out that, whereas the average time required for a student to achieve his R. M. A. was well below 50 hours, some pilots required more than twice this time.

individual differences in proficiency. (4) Accidents were, in many instances, attributed to psychological defects in the pilot.[3] Finally (5), there were many cases of "nervous breakdown" among flyers.[4]

Centers for psychological work on aviation were established in Italy, France, Germany, England, and the United States. Most of these were under direct governmental auspices. Emphasis in each center was on selection of those best fitted for flight training.

The problem of selecting pilots was difficult because nobody knew very much about the qualifications of a good pilot. Job analysis, which had already been introduced in industry, was unknown in aviation. Italian psychologists first realized the necessity of a job analysis for flying and attempted such an analysis through a survey of "successful," "mediocre," and "unsuccessful" pilots. From this it was concluded that

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[3] Hennon (52, p. 104) tells of 74 trainees discharged after they had, between them, wrecked 30 planes. "One man...was given 55 hours of flying instruction and wrecked five ships before he was relieved as 'unadaptable for further training'." According to Anderson's (2) study of 58 crashes in two British air schools during the last war, 42 were due to poor judgment, including possibly poor vision and long reaction time, 7 to "loss of head," and 4 to "unsuitable temperament" (pp. 30-31).

[4] During the World War there were instances where 50 percent of the candidates for air service were reported as suffering from a "neurosis" while in training. (7, p. 6). Prior to 1925, 80% of the permanent and temporary groundings in this country were attributed to "nervous instability" (14, p. 52).

> A good pilot is one who to a sufficient speed of perception and to a notable degree of extension and distribution of attention, adds constancy, precision, coordinating ability of the psychomotor activity, and who possesses a sufficient inhibitory power of emotive reactions not to be disturbed in the above functions on account of emotional stimulus (25, p. 116).

This analysis is of interest historically but, like many others of the same period, it is of doubtful value because (1) the criteria upon which the original classification into "successful," "mediocre," and "unsuccessful" was based were not stated; (2) the number of pilots in each group was not reported; and (3) standard tests by means of which the items mentioned in the survey could be measured in a reliable manner were not available.

Italian psychologists attempted to measure all of the items involved in the job analysis, but they paid particular attention to speed of reaction and calmness in emotion-provoking situations. Their work is especially notable because it introduced the complex coordinator type of test, involving a simulated cockpit, and utilized the "psychological profile," a graph showing the individual's relative standing in each of the traits measured.

The French were concerned primarily with simple reaction time and physiological responses to emotional stimuli. Underlying these tests was the assumption, not demonstrated in subsequent investigations, that fast reactors and emotionally calm individuals make the best aviators.

In Germany, emphasis was on perceptual and memory tasks. Candidates were required to observe and react to visual and auditory details of

situations simulating those which might occur while flying over a terrain or while engaged in combat. They were also called upon to report details witnessed during simulated and actual flight.

British psychologists used a wide variety of tests, but stressed no particular one. However, considerable attention was given to the athletic history of candidates. British psychologists also did some preliminary work on the psychological effects of oxygen deprivation, but maintenance of the flyer, rather than selection and classification, was emphasized.

In the United States, efforts were directed toward measurement of reaction time, motor dexterity, judgment, attention, intelligence, association, personality, and several other items. Perhaps the chief contribution of American psychologists was their insistence upon trying out tests and test batteries to see how well these predicted success or failure in flight training, an insistence, in other words, upon controlled research as a preliminary to using the tests in practice. Investigators in other countries were prone to use tests because they "looked reasonable" without first determining by experiment whether there existed a significant relation between test scores and flight performance. The relation was taken for granted, not determined by research methods. According to Henmon (52), a promising battery of tests was eventually worked out by American psychologists, but before

it could be put to practical use the war ended.[5]

The psychological effects of oxygen deprivation and the value of the Barany chair[6] test of equilibrium in selection of flyers were also investigated in the United States with particular reference to the selection and classification of pilots.[7]

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5 In the United States, work on aviation psychology came under the auspices of the National Research Council Committee on Psychological Problems of Aviation and of branches of the military service. Among those who served in various capacities on the N. R. C. Committee from 1917 until the end of the war were Burtt, Stratton, and Thorndike (Chairmen) and Miles, Troland, Watson, Brown, Maxfield, and McComas. Several psychologists served in Air Personnel and in the Committee on Classification of Personnel. In addition to these, and others on the N. R. C. Committee, more than fifty psychologists were eventually working on various projects in the psychology department of the Medical Research Laboratory at Mineola, L. I., under the direction of Knight Dunlap, and later, Stratton. The Mineola laboratory was established and remained under the general direction of the Medical Research Board appointed by the Surgeon General's Office. John B. Watson served as a member of this board (28, 52, 108, 113). Several American psychologists studied aviation problems overseas (25).

6 This is a special form of swivel chair in which the candidate was rotated rapidly and then tested to see how accurately he could touch the examiner's hand, held directly in front of him. The duration of eye movements (nystagmus) following rotation was also noted (see pp. 39-42).

7 In 1922, McComas (66) wrote, in popular style, a book entitled The Aviator, which includes a very brief and general discussion of the work of psychologists in the war. This book has escaped the attention of many present-day psychologists, perhaps because the word "psychology" does not appear in its title. It deals with the following topics: the aviator as a machine, nerve and nerves, controlling the plane, the sense of motion and balance, vision in the air, other senses, the feel of the ship, oxygen and efficiency, doing stunts, selecting the aviator, types of airmen, and the pilot as a personality. Much of the book is an expression of the author's views on tasks which confront the aviator and on the qualifications of a good aviator. There is also a discussion of alleged differences in pursuit pilots, bombing pilots, and observers. Parts of the book rest heavily, and uncritically, upon the material in Air Service Medical (111).

A survey of the types of tests developed during the first World War to aid in selection of pilots gives a more systematic conception of the scope of aviation psychology at that time than does a general survey of work in each of the countries involved. All work done during the first World War falls under one or more of the following categories: measurement of the speed of simple reactions, complex reaction tests, other tests of psychomotor processes, combinations of psychomotor and intellectual scores, investigations of sensory processes, personality observations, and investigations of psychological functions under low oxygen tension.

## 2. SPEED OF SIMPLE REACTIONS

Measurement of simple reaction time involves a determination of the time which elapses between the flash of a light, sound of a buzzer, or onset of some other stimulus and the subject's reaction, which may be that of squeezing, pressing on, or removing pressure from, a key.

The instrument customarily used to measure speed of reaction is known as a chronoscope. The d'Arsonval chronoscope illustrated in Figure 1 was widely used during the last war in testing the speed of simple and complex reactions.

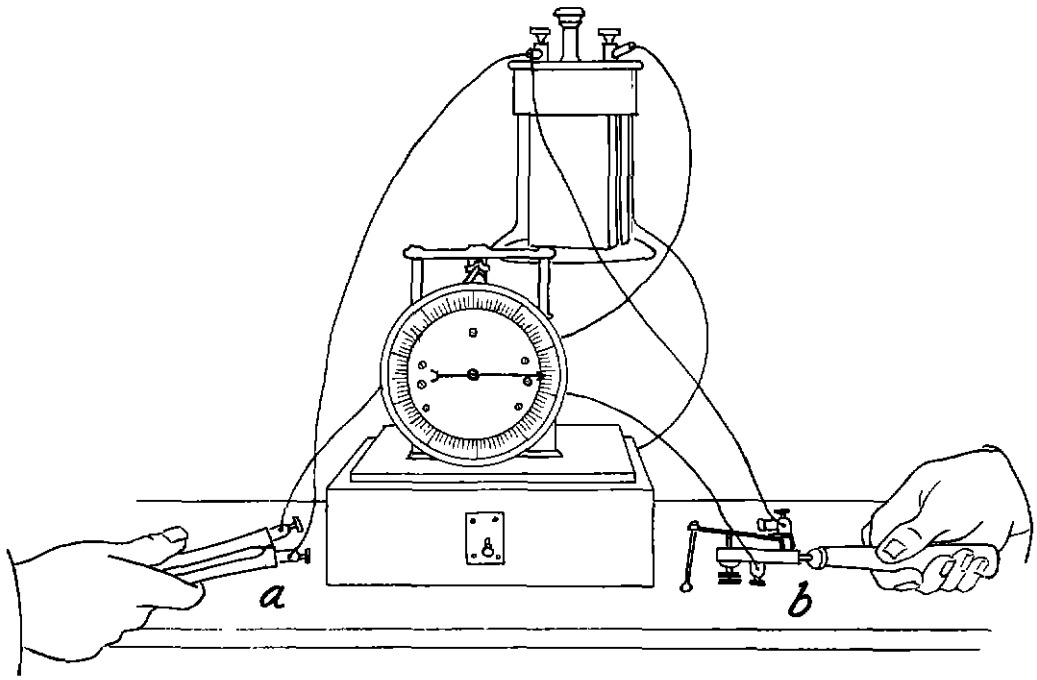


FIG. 1

FIGURE 1

THE D'ARSONVAL CHRONOSCOPE

The candidate sat with the response key, a, in the palm of his hand. When the tester struck the top of the table (or the candidate's hand) with his key, b, he not only gave a signal for response, but at the same time opened an electrical circuit which allowed the chronoscope pointer to become engaged with a clockwork device. This caused it to sweep the dial once per second. As soon as the candidate squeezed his key, a circuit connected with a magnet, which disengaged pointer and clockwork, was closed. Since the tester's signal started the pointer revolving and the candidate's reaction stopped it, the elapsed time, read in 1/100 sec. units, represented the latter's speed of reaction (after Binet and Camus and Nepper).

The time required for simple reactions was first used as a test for aviators by Camus and Nepper (23) in France. Similar methods were eventually adopted by other French investigators (49) and by the English (4). Speed of reaction to such stimuli as movement of the chronoscope pointer, the sound of a small hammer, and a touch on the hand were measured with the d'Arsonval chronoscope. Characteristically, Camus and Nepper did not indicate how the value of the test was determined and how results were actually used in selecting or rejecting candidates although they said that "good" candidates had a reaction time (average of 10 tests) of 19/100 sec. in responding to visual and of from 14/100 to 15/100 sec. in responding to auditory or touch stimuli. A later study of 1,000 candidates by Guillain and Ambard (49) showed that some who failed to achieve a sufficiently rapid reaction to meet the standard when first tested frequently did so following encouragement. These investigators concluded that simple reaction, taken alone, should not be used for rejection of candidates.

Gemelli (37, 38), an Italian psychologist, also used tests of simple reaction time. Twenty tests per candidate were made for visual and auditory stimulation under each of the three following conditions: sensory set, requiring the candidate to concentrate upon the stimulus and react as soon as it was perceived; motor or muscular set, requiring the candidate to concentrate not upon the stimulus as such, but upon his muscular reaction; and mixed set where the set (sensory or motor) varied from one test to another.

Gemelli took cognizance not only of the average reaction time under each of these conditions for each kind of stimulation, but also of the

average variability of reaction of each candidate during each series of 20 tests. Variability was determined by averaging differences between the time of each reaction and the average time for 20 reactions. The reaction time of experienced aviators was also measured so that standards might be set for rejection or acceptance of candidates. As a result of these studies, Gemelli concluded that rapid reactors, and especially those whose time does not fluctuate a great deal from test to test, are preferable to slow and variable reactors. Although Gemelli reports no definite standards, Gradenigo (48) says that the acceptable limits (apparently based upon sensory set) were 20/100 sec. for visual and 17/100 sec. for auditory stimuli.

From August 1917 to November 1918, 169 out of a total of 6,097 candidates were rejected on the basis of reaction time alone. This represented six per cent of all rejections. Nothing was said, in this connection, about use of variability as a criterion. However, Saffiotti (101) reported that the limit of average variability allowed was 3/100 sec.

Gemelli (37,38) also measured the reaction time of five pilots, two "good", two "inadequate", and one "excellent", before and after a flight of one hour. He claimed that slower and more variable reactions occurred after than before flight but that "poor" aviators exhibited a greater change than "good" ones. The number of candidates was, of course, too small to establish any such relationship on a reliable basis.

Saffiotti's (101) research included data on simulated reaction times. He found that some candidates and pilots exaggerated their reaction times in order to be declared temporarily or perhaps permanently unfit. When values

went far above acceptable limits the deception was easily detected and a reprimand brought them down. Values closer to the acceptable limits were difficult to detect, but the astuteness required successfully to fake reaction times barely beyond the limits was rare. Saffiotti mentioned, but did not describe, a device used by him to detect simulated reaction times.

English selection boards measured simple reaction times as the French and Italians had done, but, unlike them, placed little confidence in the results.

The American work on simple reactions was significant chiefly because, for the first time, an effort was made to determine experimentally whether or not reaction time actually differentiates good and poor flyers; in other words, whether one can predict flying skill from reaction time. While the work was far from achieving the standard of acceptability imposed by scientific research, there was nevertheless a recognition of the problem and an attempt to face it. Henmon (52) tested 150 cadets at each of two fields.[8] At each field 50 "very good", 50 "very poor", and 50 flyers of unknown ability were involved. Each individual of the "very good" or "very poor" group was in it on the basis of officer's ratings and report cards. Reaction time failed to differentiate the "good", "poor", and "unknown"

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[8] This is the first published attempt in this field to "test" a test on two separate groups; in other words, to determine whether results obtained in one group will hold up in another. Today, such a check (cross validation) is regarded as a necessary procedure preliminary to using tests in practice.

groups and a statistical analysis of the results showed that simple reaction time had no value in predicting the rated skill of the students and pilots represented in the research.

Dockeray and Isaacs (25) carried out a somewhat comparable study in Europe and their findings were similar to Henmon's. On the basis of their own and of earlier work, they expressed doubt concerning the value of simple reaction time measurements in pilot selection, but suggested that the time required for complex reactions might have value.[9]

### 3. COMPLEX REACTION TESTS

Gemelli (37,38), Romagna-Manoia (100), and Azzi (9) describe complicated tests of so-called "choice reaction". Gemelli used a simulated cockpit and a lever which, like the control stick of a plane, the candidate moved in any one of four directions. The stimulus was the flash of a lighted arrow pointing in the desired direction or, in some tests, four lights arranged in the form of a cross, each light signaling a different direction of movement. Stimuli to which no response was to be made served to complicate the situation. Average reaction times were between 40/100 and 50/100 sec.

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[9] There is evidence from more recent work that a person's average speed of simple reactions lacks stability, hence cannot, like his handwriting or his fingerprints, be used to differentiate him from others. Recent unpublished research done by Macvaugh at Tulane University shows, for example, that "there is a systematic effect of practice, which manifests itself through some thousands of reactions, and that individuals in good condition vary more from day to day, or from one series of, say, 250 reactions to another, than one individual during the same time varies from another. Moreover, these temporal fluctuations are not due to chance" (communication from H. M. Johnson). Today, because of findings during the last war, and subsequent research like that just mentioned, little if any attention is being given to simple reaction time in selecting pilots.

Romagna-Manoia's device was similar to Gemelli's and so were the time and variability scores obtained. Azzi describes an apparatus with two hand and two foot keys which were to be used in response to single lights or to combinations. Sometimes two lights requiring two reactions at once were exposed. At other times, auditory and visual stimuli, each calling for a different reaction, were used. The stimulus portion of the apparatus, when visual stimuli alone were involved, consisted of five lamps, two above and two below a central lamp. Reaction time was measured with a d'Arsonval chronoscope. The upper right-hand light called for a response of the right hand, the lower right-hand light for a response of the right foot, and similarly with the left-hand lamps. The average reaction time was approximately 50/100 sec. and the average deviation 12/100 sec. The average per cent of errors was eight. Candidates were rejected for times above 70/100 sec. and for average deviations above 22/100 sec. The maximum error score allowed was 26 per cent.

American tests of complex reaction time were similar to those of the Italians. One apparatus included a seat, stick, and rudder bar assembled as in a plane (108). The stimulus was a card containing an arrow and a letter. An arrow pointing to the right indicated that the right and an arrow pointing to the left indicated that the left foot was to react. The appropriate stick movement was to the right for the letter R, to the left for L, back for B, and forward for F. Accuracy as well as speed was scored. Fifty cadets were tested. After preliminary practice each cadet was given 20 trials on each of two successive days. The quickest had an average reaction time of 64/100 sec. and the slowest of 1 and 64/100 sec. The most

accurate made no errors and the least accurate 29 errors in 40 trials. Little apparent relation between instructor's ratings of the cadets and their speed or accuracy of reaction was found.

A simpler choice-reaction test than those already described was that of Burtt (21) in which the subject was required, by using the stick in some tests, and the wheel in others, to right a simulated plane when the platform on which he was seated tilted to the right, left, front, or back much as does an airplane. Reaction time for this maneuver was similar regardless of whether stick or wheel manipulation was involved. Hemmon (52) used a modification of this test on 150 students at Kelly Field. The stimulus was a tilt to right or left. Actual times of reaction are not given, but it is reported that the relation of test scores with ratings for flight ability was negligible. When the time required to respond to tilt was subtracted from the sum of simple auditory and visual reaction times in order to obtain an "equilibrium differential," the relation of scores to flight officer's ratings was still of little or no significance.

The Ruggles orientator. Another, but more complex test of the same nature as those just mentioned, but which did not involve measurement of reaction time, was the Ruggles orientator shown in Figure 2 and described in the legend.

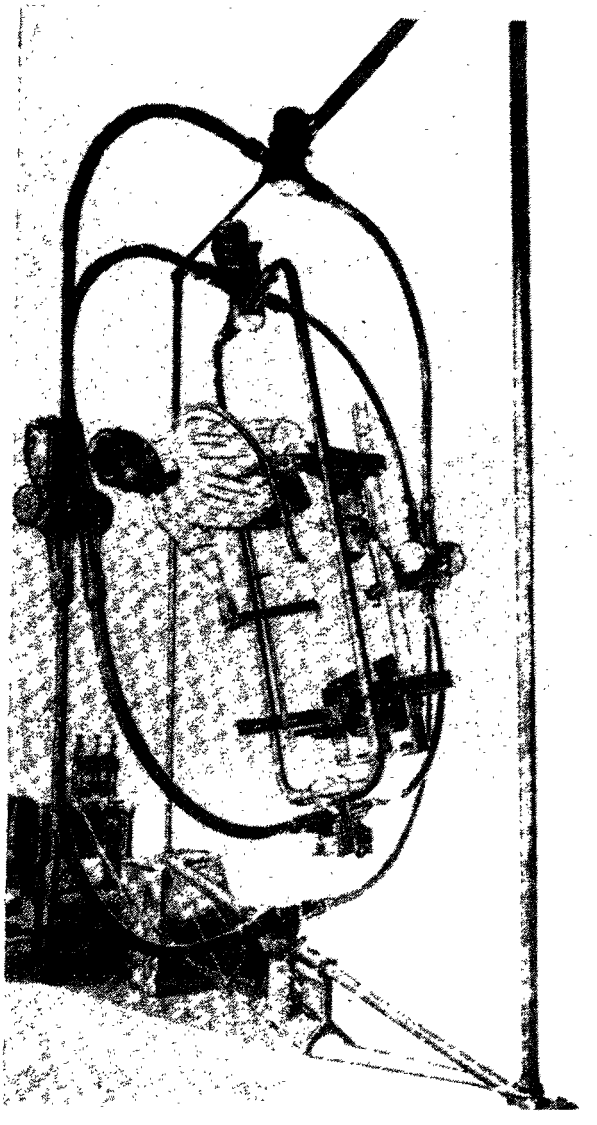

FIG. 2

FIGURE 2

THE RUGGLES ORIENTATOR

One of the many positions which may be assumed by the candidate is shown. The apparatus is like the cockpit of a plane suspended in concentric rings. Movements are possible in all directions and are governed by the individual seated in the machine, through motions of the stick held in his hand. Strapped in the orientator he is able to execute loops, spirals, etc. (From Air Service Medical, pp. 262-263).

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According to the writer in Air Service Medical, who like many others in this field, offers no proof to support his assertions, the orientator enables flyers to develop a tolerance for acrobatics which dispels vertigo. He says, moreover, and also without exhibiting evidence, that the candidate who uses this device

> will learn to orientate himself in new and rapidly changing positions of the body and to perform properly the complicated acts necessary to control an aeroplane while flying with his head down, etc., which entails an entirely reversed relation to external objects, a condition in itself most disturbing and pregnant with possibilities of disaster.
>
> The orientator placed in the ground and flying-schools will save many lives and machines, shorten materially the time of flying instruction, and develop a large number of stunt flyers (111, p. 363).

Bauer (14) writing after the war, claimed that the Ruggles orientator predicts "flight difficulties," but again there was no search to determine its actual value. Although the time required to right the cockpit after it had been changed to a new position by the tester was not measured, such measurement would have served the same purpose as Burtt's test (21) and the Reid reaction apparatus discussed below.

The Reid reaction test. The Reid apparatus (97) was invented in England and used by the R. A. F., by the Polish Air Force (64) and, more recently, by the German Air Force (59). The apparatus had four groups of electric lamps arranged centrally around a speed indicator. These were colored red or green and indicated the position of the machine in space - whether "flying" straight, to port or starboard, and whether banked or on level keel. Degree of alteration of the "plane's" position in one or more

spatial dimensions was shown by the number of lamps illuminated in one or another group. Movements of the rudder bar or stick, acting through an electrical system, extinguished these lights as soon as straight and level "flight" was achieved. Two lights were always on during straight and level "flight". A d'Arsonval chronoscope recorded the time required to make the movements necessary in righting the "plane". The entire apparatus was set up within a plane fuselage.

The procedure used in testing was as follows: The candidate sat in the machine, the mechanism was explained to him, and a few preliminary trials were given. He was then given a series of trials involving movement of stick to right and left, leg movement of the rudder bar to right and left, combined movements of one arm and leg simultaneously - usually the stick to one side with full rudder to the opposite side - a position corresponding to that involved in a "spin." Effects of distraction were measured after a Klaxon horn sounded unexpectedly.

Average reaction times and variations were obtained from two groups of pilots differing in experience, and from a group of inexperienced candidates. The number of trials on which the averages were based and the number of subjects in each group were not reported. However, the data suggest increasingly faster reactions for those with greater experience. There was no attempt to determine how results obtained on these tests are related to actual flight performance. Nevertheless, possible uses of the device are mentioned. These are: (1) testing "ability to fly and land successfully," (2) periodic tests of "the rate of progress and of acquisition

of flying skill," (3) "training pupils to acquire on the ground those particular coordinations necessary for aeroplane control," (4) classification for diverse forms of service - the fastest times "indicating delicacy of adjustment would suggest an aptitude for scout machines" and (5) recording reaction time of a pilot while actually flying - the "effects of high altitudes and diminished oxygen tension would then be automatically recorded" (97, p. 53).

The "LVN" test. At Mineola, there was an attempt to classify candidates in terms of their resistance to the effects of low oxygen tension. In this work, psychologists used the so-called "LVN" test, thus designated because it called for reactions to lights, changes in a voltmeter (later an ammeter) reading, and changes from the normal speed of a motor. The "LVN" apparatus is shown in Figure 3, the legend of which describes it and indicates the reactions required. This test, finally administered to all candidates at Mineola (about 7000), and used extensively elsewhere, comprised three tasks to be performed one after another, but in a random order and in accordance with certain regulations stated in instructions given beforehand. According to Dunlap (29), the rapid shifting from one task to another required in this test is similar to that called for in flying. The tasks were: (1) touching the corresponding screw as each of the 14 lamps appeared in random order, and avoiding the washer; (2) adjusting an ammeter needle by means of a rheostat as soon as displacement was evident; and (3) restoring a motor to its original speed as soon as this was heard to change. Presentation of the lights was controlled by an automatic timer.

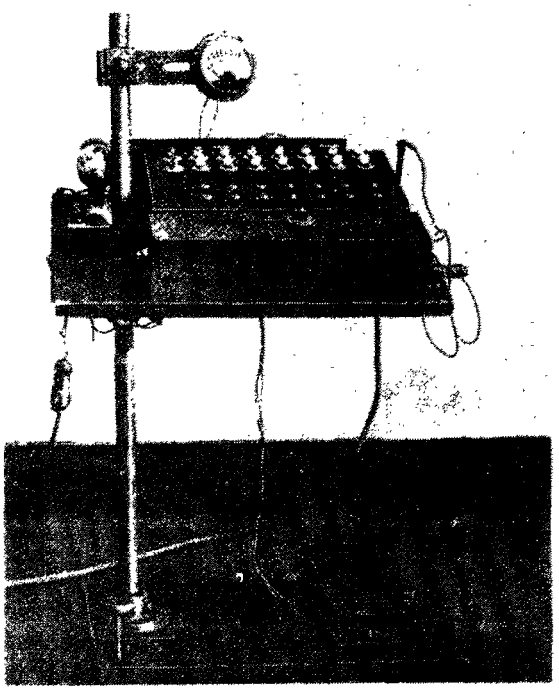

FIG. 3

FIGURE 3

THE "LVN" APPARATUS

The apparatus consisted of three separate units; (1) A series of 14 lamps was arranged in two rows of seven each, with two similarly arranged rows of contact buttons, each surrounded by a washer. There were also a green check lamp, a red error lamp, and a stylus. When a stimulus lamp was illuminated, the corresponding contact button became "alive," and, if touched with the metal tip of the stylus, caused the green check lamp to light. If the washer surrounding any of the buttons was touched with the stylus at any time, the red error lamp went on. (2) Two ammeters were connected in series with two rheostats, one facing the psychologist and one the candidate. A change in the resistance made by the psychologist at his rheostat led to a change in the ammeter reading. This was compensated for by a change in the candidate's rheostat, which consequently restored the pointer to its former position. (3) A motor was connected in series with a rheostat under the table; a two-way switch, also under the table near the psychologist; and a rocking pedal two-way switch under the table beneath the candidate's foot. Cutting out of part of resistance of the experimentor's rheostat increased the speed of the motor. Cutting in resistance slowed the motor. By proper use of his pedal, the candidate could restore the motor to its original speed. (From Bauer, 14, p. 107).

Instructions were as follows:

Instructions

Read carefully

You have three things to do:

1. Lights

When a light flashes, touch with the stylus the top of the corresponding screw-head. Do not touch the washer.

2. Ammeter

Watch the ammeter and by adjusting the rheostat (using the right hand) keep the ammeter at the designated mark.

3. Motor

Keep the motor at low speed by maintaining the proper positions of the pedal. When the motor speeds up reverse the pedal and hold it in its new position until the speed again decreases.

Notes

(a) The lights are of first importance, i. e., if a lamp lights when you are reacting (or are about to react) to the ammeter hand, react to the light first and then go back to the rheostat.

(b) When you touch with the stylus the contact-button corresponding to a light, the movement of the hand and arm should be "free" (neither hand nor arm should touch table, rheostat, or board). The hand may at other times rest on the slide of the rheostat.

(c) Do your work with Accuracy, Neatness, and Promptness. Do not bang, slam, or jab. (11, pp. 108-109).

A set of symbols was used in recording the subject's reactions. The general performance level of each reactor was indicated by means of a special formula worked out by Bagby and Ross.

No research to determine how scores on this test are related to aeronautical skill was undertaken and the results on the 7000 or so candidates

tested at Mineola were never analyzed in detail (see pp. 47-50).

Dunlap[10] says,

> We could rate fliers on the LVN set-up, and train "psychologists" to use it at various air fields, but we were not allowed to find out whether the ratings really meant anything as regards altitude flying. As Major ____ expressed it, "We have no time for scientific research; this is war."

German investigations of complex reactions. German investigations were extremely complex and laid stress upon accuracy of observation, not upon speed of reaction. Thus in one of Stern's (106) experiments, the candidate, who sat in the center of a room with a moving terrain below and representations of French and German planes above, was required to manipulate a certain switch for French planes, another for artillery positions, another for a loud sound, and so on for six switches. He was not to react to "German" planes. Such factors as reaction time to enemy planes, false reactions (to German planes or other targets) and reaction failures (viz., not responding to a French plane or an artillery target) were noted.

A test devised by Kronfeld (57) has much in common with that of Stern. The candidate "photographed" objects which appeared on a moving terrain, the latter being represented by a painted panorama pasted over a drum which moved at a constant speed. The perspective was that of a terrain from a

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[10] Quoted by permission from personal correspondence.

Instructions were as follows:

Instructions

Read carefully

You have three things to do:

1. Lights

When a light flashes, touch with the stylus the top of the corresponding screw-head. Do not touch the washer.

2. Ammeter

Watch the ammeter and by adjusting the rheostat (using the right hand) keep the ammeter at the designated mark.

3. Motor

Keep the motor at low speed by maintaining the proper positions of the pedal. When the motor speeds up reverse the pedal and hold it in its new position until the speed again decreases.

Notes

(a) The lights are of first importance, i. e., if a lamp lights when you are reacting (or are about to react) to the ammeter hand, react to the light first and then go back to the rheostat.

(b) When you touch with the stylus the contact-button corresponding to a light, the movement of the hand and arm should be "free" (neither hand nor arm should touch table, rheostat, or board). The hand may at other times rest on the slide of the rheostat.

(c) Do your work with Accuracy, Neatness, and Promptness. Do not bang, slam, or jab. (11, pp. 108-109).

A set of symbols was used in recording the subject's reactions. The general performance level of each reactor was indicated by means of a special formula worked out by Bagby and Ross.

No research to determine how scores on this test are related to aeronautical skill was undertaken and the results on the 7000 or so candidates

tested at Mineola were never analyzed in detail (see pp. 47-50).

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height of 2000 meters. The candidate observed the objects within a field of vision restricted by the fact that he was "sighting" through a special device with his head stationary. Keys on the table in front of him were used in "photographing" particular objects. Other aspects of the situation calling for appropriate reactions were flashing lights in the peripheral field and cessation of the hum of a "plane" motor. At times a sudden flash of light occurred. This was to determine the effect of an emotional stimulus upon the candidate's reactions. Reaction time was measured in units of 1/5 second. Scoring stressed premature and tardy reactions, failure to react, and the amount learned as a result of repeated tests.

In Benary's (15) investigation of complex reactions, the candidate "shot at" arrows, forms, bulbs, etc. representing enemy positions. He did this by pressing upon appropriate keys. Note was taken of reaction time, false reactions, and omissions. The experiment is not well described and apparently no practical use was made of its findings.

### 4. OTHER PSYCHOMOTOR TESTS

Although most of the early work on psychomotor tests concerned either simple or complex reactions in which time and errors were measured, a few other tests were also used. Gemelli (37, 38) measured muscular fatigue. Galeotti (33) invented a device to test how well the candidate, by manipulating a handle, balances various resistances applied to it. He called his instrument an "ergoesthesiograph." A high relation between success in flying and test scores was claimed but not supported by published evidence.

Stratton (107) described a dexterity test requiring the candidate to balance rods varying in length. The English (25) also used a rod-balancing

test. In neither case, however, was the value of the test in relation to aviation performance determined.

Both American and English psychologists made use of tremor tests (25). In American tests the candidate held the point of a stylus in small holes of varying size for stated periods. Contacts with the side of a hole were recorded electrically. A high relation between training department ratings and steadiness was observed in a group of 37 candidates. However, this was too few subjects to establish the relation on a reliable basis. Moreover, the test was not tried out on different groups to discover whether the observed relation could be verified. English tremor tests were much simpler than the American. They merely required the candidate to draw a line lightly across a sheet of paper without resting his hand. According to Dockeray and Isaacs (25), a close relation between steadiness and flight performance was observed by the English. However, there apparently was no careful research to determine the reliability of this observation.

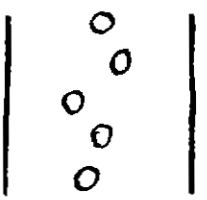
Other simple psychomotor tests mentioned in various places as having had some use in selection of candidates for flight training are body sway, strength of grip, accuracy in striking a target, and various body-balancing tests with and without the eyes closed.

Psychomotor tests of greater complexity than any of the above, yet somewhat simpler than the complex reaction tests already discussed, were certain pursuitmeter and "dotting" tests.

Pursuitmeter tests. Miles (79) developed a pursuitmeter which required the subject to keep an ammeter needle at a constant middle point by adjusting a rheostat while changes in current which threw the needle off

were being made by an automatic disturber unit. Another test, involving a pendulum pursuitmeter was also invented by Miles (78). The lower part of a moving pendulum emitted a stream of water, and motor dexterity was measured in terms of the amount of water collected by the candidate in small containers, a separate container being picked up and used for each double swing. No adequate determinations of the value of these tests in measuring aptitude for aviation were carried out.

The dotting test. An improved form of McDougall's "dotting" test (20, 67, 99, 105) was used by the British during the early days of the war as a measure of motor dexterity. The apparatus was a gravity-driven clockwork device carrying a continuous one-inch-wide strip of paper tape across a small window in the top of a desk at which the candidate sat. Small red circles appeared at irregular intervals along the width of the band as indicated below. They moved toward the candidate, who was



required to dot each circle with a stylographic pen as it appeared. The rate at which the tape traveled was regulated to keep the candidate working at maximum speed. This rate was increased until a breakdown in response occurred. The task is described as an extremely interesting one which called forth maximum effort. During the war, an improved version devised by Rivers (99) was used. There is no evidence of any attempt to determine whether, and if so, to what degree, the test results were related to aeronautical skill.

Summary on reaction time and other psychomotor tests. In the preceding pages it has been necessary to repeat, again and again, statements like the following: "No research was undertaken to discover the relation between results on this test and aviation performance" and "The test was used merely because the assumption that it tested aeronautical skills appeared reasonable."

Where research to determine the relation between speed of simple reactions and flight performance was undertaken, as in some of the American investigations (25, 108), the tests definitely were shown to lack value. Complex reaction tests carried out in simulated cockpits seemed more promising than those of simple reaction time, but only one of them was actually evaluated in terms of flight performance (108). This investigation, involving 50 cadets at an American flying field, gave evidence of only a slight relationship between test scores and flight ratings. However, subsequent research demonstrated that other complex reaction tests are quite valuable in pilot selection.

## 5. MEASUREMENT OF EMOTIONAL REACTIONS

Tests of emotional reactions in aviation candidates and pilots followed well-established laboratory technique. Camus and Nepper (23) registered the intensity and duration of changes in respiration, pulse rate, blood pressure, and muscular tremor in response to such stimuli as a revolver shot, magnesium flash, and a cold wet rag slapped on the head. Responses were registered kymographically as indicated in Figure 4.

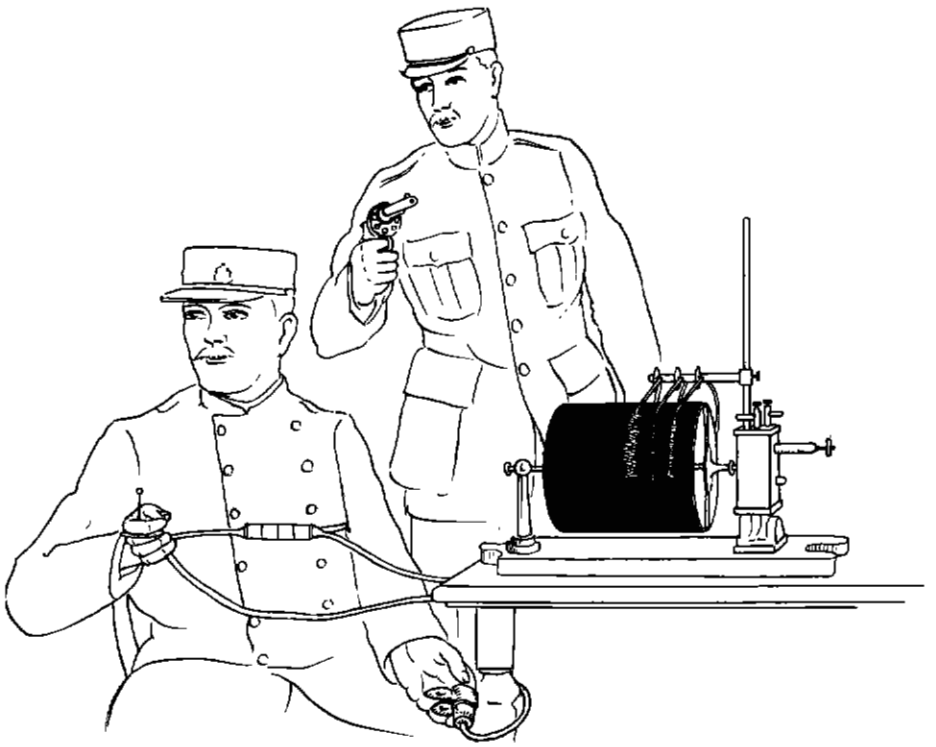


FIG. 4

FIGURE 4

MEASUREMENT OF EMOTIONAL RESPONSES

Around the candidate's chest is a pneumograph which records changes in respiration. These changes produce air pressure changes in the pneumograph, the tube leading from it, and a cup to which a rubber diaphragm and writing lever are attached. Movements of the lever are recorded on a moving smoked drum. Pulse rate and blood pressure changes are similarly recorded. A finger sphygmomanometer, seen on the candidate's left hand, serves to pick up these pulse and blood pressure changes. In the candidate's right hand is an apparatus for measuring muscular tremor. (After Camus and Nepper).

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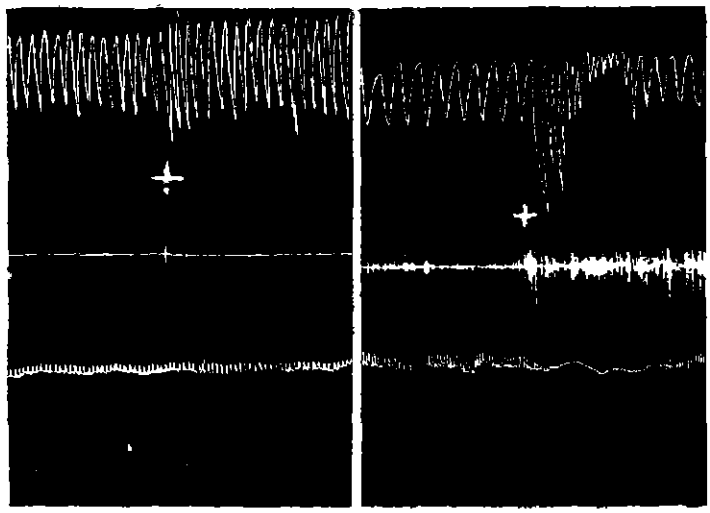
Although candidates were rejected on the basis of their responses to the above-mentioned situations, the method of selection is described in only the vaguest terms and no data are cited to show that the test actually discriminated between pilots of varying degrees of proficiency. A few cases are mentioned for illustrative purposes. According to these, the revolver shot led to a change in amplitude of breathing in a "good" candidate. A "poor" candidate, however, exhibited changes in both amplitude and rhythm of respiration. Tremor records for "good" candidates showed little and those for "poor" candidates a great deal of fluctuation following the shot. Pulse and blood pressure changes were also more marked in "poor" than in "good" candidates. Records illustrating these changes are shown in Figure 5. Reactions to other emotion-provoking stimuli are not described. How the "goodness" of a pilot was determined is also not apparent.



Good Poor

FIG. 5

"Good" candidate "Poor" candidate

FIGURE 5

EMOTIONAL REACTIONS OF A "GOOD" AND A "POOR" CANDIDATE

From top to bottom the lines in this kymograph record represent respiration, tremor, and pulse rate and blood pressure. The ↓ indicates the point at which the revolver was fired. (After Camus and Nepper).

Gemelli (37, 38) and Aggazzotti (1) used methods similar to those of Camus and Nepper. Gemelli registered respiration (abdominal and thoracic), pulse rate, and blood pressure. The stimuli were words calculated to arouse emotional responses, either in themselves or through eliciting recall of exciting experiences. Reactions were recorded kymographically and then measured by means of a glass millimeter rule. Gemelli says that he was able to "construct for each subject and for each condition, a graphic representation of the deviation of each of the three curves from normal" and that the "values obtained permitted separation of emotional individuals

from others." No experiments to determine the actual relation between emotional reactions and flying skill are reported. However, a table i Gradenigo's (48) report shows that 192 out of 6,097 candidates were eliminated because of "excessive emotionality" and that this constituted 7 per cent of all eliminations. Aggazzotti (1) gives a detailed analysis of results obtained from 723 candidates.

Gemelli also measured respiration, pulse, and blood pressure before, during, and after a one-hour flight, and is apparently the first to make such measurements during flight. However, data on only five cases are reported and his conclusions concerning changes during ascent and descent and at different altitudes up to 3,300 meters are therefore of doubtful value.

English and American investigators made little use of tests like those described immediately above. Waller (112) used the psychgalvanometer as an adjunct to the regular medical examination. This apparatus measures changes in the electrical resistance of the skin due to sweating, but available evidence does not demonstrate that such sweating is related specifically to emotion, nervous instability, or the like. However, Waller reported that candidates tested by him differed greatly in their psychogalvanic responses when threatened with and given actual burns and pin pricks. Records for one "fit" and one "unfit" candidate are reproduced in his brief report.

English selection boards (see 14, pp. 68-69) made wide use of a test purporting to measure emotion in which, while the candidate was drawing a line lightly without resting his hand, a loud noise was made. Shakiness following the noise was taken as an index of emotionality. Henmon (52)

on the other hand, found hand tremor following an unexpected pistol shot only slightly related to flight ratings.

Blood sugar changes during flight were investigated by Maranon (70) at the Madrid School of Aviation. He found hypertension, trembling, and other emotional responses more marked in students than in experienced pilots, but both students and pilots frequently evidenced hyperglycemia before and during flight. Only a few subjects were involved and there is no indication that the blood sugar test was used for selective purposes.

Free association was utilized in the United States as a means of probing for fear reactions in relation to aspects of flight (86, 113). In these tests a word was given and the candidate responded as quickly as possible with the first word which came to mind. Parsons (86) used 100 stimulus words, 50 of which related to aviation. The time required for response, and the words given, were recorded. Data are offered which, although an inadequate number of subjects was involved, suggest some relation between scores on this test and success in flight training.

In addition to, or in lieu of such tests as we have described, estimates of medical examiners concerning a candidate's emotionality were often used in selection (see p. 44).

## 6. TESTS OF INTELLECTUAL PROCESSES

Although tests of attention and perception, judgment, memory, and general intelligence were used by a number of belligerents as a means of selecting pilots, none of these played as large a role as other types of tests already discussed.

Attention and perception. Attention has often been stressed in relation to aviation skill. Gemelli (37, 38) believed that the pilot must possess both "depth" of attention and ability to attend to several events simultaneously. He measured "depth" of attention by exposing a small figure for a short period of time. The candidate was given successively longer exposures until able to "apperceive" the figure. Records were kept of the time of exposure required for a correct response. Candidates failed this test if the time of exposure required for simple figures was greater than 6/100 sec.

In order to measure the "breadth" of attention, five small figures were exposed simultaneously for successively longer periods until all five (different ones in each exposure) were reported correctly. The qualifying score was five figures correct after 1/10 sec. exposure. Again, as in much of Gemelli's work, little or no evidence is cited to show that the test results were actually related to flight performance. Attention tests somewhat similar to those described by Gemelli were also used by Galeotti and Cacciapuoti (35) Herlitzka (53), and Galeotti (34).

Saffiotti (101) describes briefly and not very clearly, an attention test which is apparently of the cancellation variety. The materials consisted of five series of 20 symbols each. Relevant symbols were scattered in such a manner as to form a labyrinth through a mass of irrelevant ones. The subject crossed out the appropriate symbols in going through the mass. Errors and time were recorded.

Attention scores were not used alone in selecting candidates, but were combined with scores from other tests as shown in our discussion of psychological profiles (p. 34 ).

The LVN and McDougall dotting tests, already discussed, have also been regarded by some as measures of attention. Burt (20) says that the dotting test measures "continued maximum voluntary concentration of attention" (p. 153).

Judgment. Judgments of distance, speed, and time are said to play a large role in aviation, hence their measurement for selective purposes is not surprising. Bachman (10) used tests of judgment in selection of naval aviators. These involved estimation of length of sticks, of the relative speed of four revolving discs, and of the time required for sand to flow from one container to another. A type of formboard was also used. No data on the relation of such judgments to flying skill were obtained.

Stratton, McComas, Coover, and Bagby (108) measured judgment of curves and of the relative speed of two white spots moving along converging lines in a horizontal plane. Apropos of the first-mentioned test these investigators say,

> The ability of the aviator to estimate the course that his airplane will take as it descends is of great importance...This ability undoubtedly depends in part upon acuity of vision, balance of the ocular muscles, judgment of spatial relations, all of which are engaged in the work of this test, namely: that of estimating the distance of the point at which a parabolic curve, if continued beyond a given segment, intersects a horizontal plane (p. 409).

The relation between scores on such tests and aviation rating was too small to make the tests of practical value in predicting aviation ability.

Memory. Since the pilot is called upon to remember routes that he has once traversed and to map locations, there have been a number of attempts to measure this aspect of aviation performance. Benary (15) devised the most

elaborate tests, but there is no evidence that they were evaluated in relation to known skill or put to any practical use. One test required the subject to recognize, in a complicated map of roads, villages, and artillery positions, a small detail previously shown on a separate card. In another test (route memory) the task was to follow, in the midst of great details, a route previously indicated in isolation. Still another test, carried out within the laboratory and then in a plane under natural conditions, called for recognition of a small detail previously represented in isolation. Five out of six subjects given this test in the laboratory and then in the air made a poorer score in the air than in the laboratory. Recognition of geometrical figures and reproduction of a flight route after landing were also tested.

A much simpler task than those of Benary was used by Stratton, McComas, Coover, and Bagby (108) to test route memory. A maze pathway was drawn on cardboard and covered with a movable shield containing a hole of 2 cm. diameter in such a manner that only a small portion of the pathway could be seen at one time. The candidate moved the hole along the maze pathway from beginning to end and back again. He was then called upon to traverse a larger and more complicated pathway. Four trials, two on each of two successive days, were given and the time required to go from entrance to exit noted. For every entrance into a blind alley, a return to the entrance was required. No significant relation of maze scores to flight rating was found.

General intelligence tests. The United States was the only country to make any use of general intelligence tests in selecting flyers during the last war. Even here there was relatively little use of such tests in

selection of aviators. Thorndike's mental alertness test, designed to measure a variety of mental functions, was eventually adopted by examining boards. However, both Henmon (52) and Thorndike (110) reported that there was only a slight relation between scores on this test and flight ratings.

## 7. COMBINATIONS OF PSYCHOMOTOR AND INTELLECTUAL TEST SCORES

An important aspect of Gemelli's work was his use of the psychograph or psychological profile (previously suggested by Rossolimo) to get an overall view of the candidate's psychological status. He felt that this general overview had greater value than measures of single traits. Twelve measures of psychological processes were included in the psychograph. These are represented in Figure 6, which shows psychographs for candidates diagnosed as "excellent", "inadequate", and "emotionally inadequate." How much actual use was made of such psychographs in selection is not apparent from Gemelli's discussion.

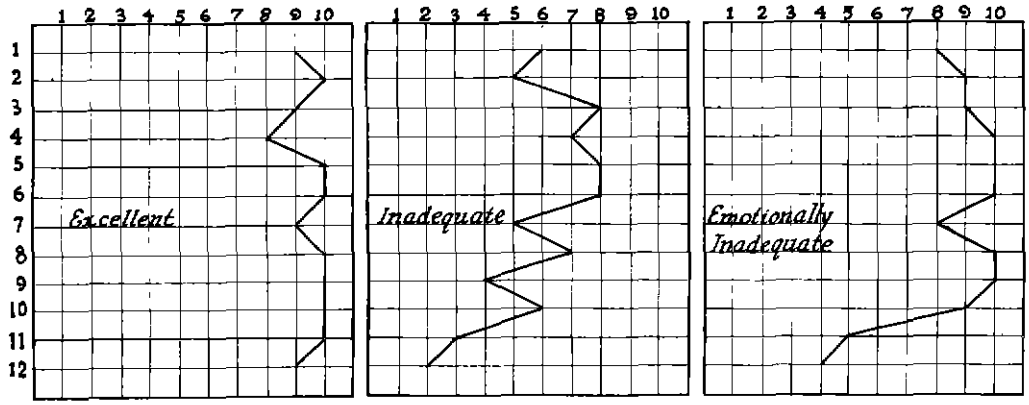



FIG. 6

FIGURE 6

PSYCHOPHYSICAL PROFILES OF AVIATION CANDIDATES

Scores are in terms of decile ranking. The psychophysical measures are: (1) concentrated attention, (2) breadth of attention, (3) recognition, (4) judgment, (5) reproduction, (6) recognition of colors, (7) observational aptitude, (8) reaction time - auditory, (9) reaction time - visual, (10) reaction time - tactile, (11) emotional response - respiration, and (12) emotional response - circulation. (after Gemelli).

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American investigators used various methods of combining scores for separate tests. Composite scores thus obtained were usually related more closely with officer's ratings of flight performance than were single scores. Hennon (52) describes how he developed a composite score for emotional stability, perception of tilt, body sway, auditory reaction time, equilibrium choice reaction, equilibrium differential, and mental alertness. According to Hennon (p. 107) who used the combined tests on flyers and cadets at two fields, this composite score was sufficiently related to aviation ratings to permit its use "for prognosis with some confidence." He presents a table based upon research with 100 cadets and flyers at Kelly Field. This shows that those who made high composite scores required significantly fewer hours of dual time then did those who made low ones, that a large proportion of the low scoring group was suspended, relieved or discharged, and that poor flying school reports predominated in low scoring and were rare in high scoring candidates.

Hennon also gave the tests to 50 cadets of unknown ability who had just reached the field. On the basis of combination scores he then submitted the prediction that five out of the 50 either would be discharged or would learn with difficulty and that two would show special aptitude. These predictions were realized.

> Of the five men three were discharged after 4, 20, and 22 hours of instruction respectively. One of these men wrecked two ships completely. The fourth man was relieved from flying at one time and brought before the Discharge Board but was given another chance and finally commissioned after 85 hours of flying when the median time for his class was 60 hours. The fifth man was commissioned after 93 hours of instruction. The Officer in Charge of Flying said of

> these men that they did "fair" work. The two men who were picked to show exceptional aptitude were commissioned as pursuit pilots and their work characterized as "very good". One of the men made remarkable progress and was commissioned after 43 hours of flying when the median time was 70 hours (52, p. 108).

Although the test battery was given to 150 flyers and cadets at each of two fields, only data from one field are reported. Thus there was, as far as one can tell from the published report, no verification, on another group, of the relationship observed in the group at Kelly Field. Nevertheless, the Personnel Section of the Air Service was convinced of the value of Hemmon's test battery and authorization to proceed with its introduction was given. Four units were set up in connection with examining boards, but the Armistice was signed before further practical use could be made of the battery.

Stratton, McComas, Coover, and Bagby (108) report only a slight relationship between aviation ratings and combined scores for judgment of speeds, judgment of parabolic curves and complex reaction time. They point out, however, that the number of cases involved (50-70) was too small to allow a conclusive check on the predictive value of their test battery and that aviation ratings are unsatisfactory because of weighting by military, social, personal, and other qualifications irrelevant to aviation skill as such.

## 8. INVESTIGATION OF SENSORY PROCESSES

Sensory requirements set by aviation examining boards were invariably determined on an <u>a priori</u> basis, and only in some instances modified later in the light of results obtained. All countries eventually had somewhat similar standards.

After consulting physiology texts, those in charge of U. S. examinations for aviation candidates in 1912, set standards which, in the light of the numbers eliminated by them, seemed too high. Five years later the original examination was modified. The revised sensory aspects of the examination, and standards, were selected after consultations with eye and ear specialists, but without any attempt to test their actual relation to flight performance. This revised examination, known in its entirety as Form 609, was first applied during the first World War. The number of applicants tested was 100,000. Over 30 per cent of these were rejected. Of this percentage 6.9 was reported as due to visual, 1.2 to hearing, and 2.0 to equilibratory defects. A breakdown of the 6.9 per cent rejected as visually unfit shows that 3.3 per cent failed in visual acuity, 1.0 per cent in color vision, 0.7 per cent in muscle balance, 0.5 per cent in stereoscopic vision, and smaller percentages in peripheral vision, pupillary reactions, and eye movements (7, pp. 30-33). These figures do not include individuals eliminated on account of two or more defects. The defects in such cases were not specified. Armstrong says that, "From studies of statistics of individual units it was found that where candidates failed on two or more counts, visual defects were present in at least half of the cases" (7, p. 33). However, no evidence is presented to show that the significance of visual defects for flight performance was experimentally determined.

The visual, auditory, and equilibratory requirements of Form 609 and the means of testing for their presence or absence are summarized by Armstrong (7) as follows:

In the examination of the eye a history of the use of glasses, headaches, lacrimation, scotoma, photophobia, and previous or present eye trouble was obtained. If marked they were considered disqualifying. Glaucomatous symptoms, night blindness, or asthenopia disqualified.

Ocular movements were tested by having both of the candidate's eyes fix the examiner's finger which was then carried in the four directions, right, left, up, and down. The movement of each eye was required to be regular and identical.

The pupils were tested for reaction to light and accommodation and interocular tension was tested roughly by palpation. Inspection of the eye was done to detect disease or pathological conditions which would tend to cause blurring of vision. Ocular nystagmus was determined and if rhythmical and 40 degrees or less laterally was cause for rejection.

The field of vision was tested by the examiner moving his finger in from the periphery in the different meridiens and comparing the candidate's field of vision with his own. A restricted field of vision disqualified. Color vision was tested by means of a Jennings test set and if confusion was encountered, red and green colored lights were used before rejecting. Eye muscle balance at 20 feet was measured by means of a phorometer, Maddox rod, and rotary prism. More than one degree of hyperphoria or more than two degrees of esophoria or exophoria disqualified.

The Snellen test card was used for visual acuity and the Jaeger No. 1 test type for near vision. 20/20 vision in each eye was required in the former and not more than 11 cm. distance at age 20, 13 cm. at age 25, and 15 cm. at age 30 in the latter. The pupils were dilated with 5 per cent euphthalmine and an ophthalmoscopic examination of the fundus made. Refractions were not required.

Hearing acuity was tested by both the whispered voice and the watch test. A finding below normal, i. e. below 20/20 for the voice or 40/40 for the watch disqualified. Other abnormalities of the external ear such as small or tortuous openings, the presence of pus, perforation, scars, retraction, or evidence of past or present inflammation were causes for rejection.

The vestibular tests were extensive and included nystagmus time, past pointing, and falling after turning the candidate in a Barany chair. The caloric test was also used (pp.31-32.)

Many of these tests, as administrered, could not furnish objective and consistent measures of the sensory traits. Psychologists questioned the examination on these grounds and also because the selection of both the tests and standards was on an a priori and not an experimental basis. The chief criticism was aimed at the Barany chair test of equilibrium which was highly publicized as a means of selecting pilots (111). The Medical Department had been rejecting candidates whose nystagmus time following 10 turns in 20 seconds fell below 16 seconds and whose pointing behavior following rotation failed to conform to arbitrarily specified standards.

Critical evaluation of nystagmus requirements. Dunlap and other psychologists at Mineola questioned the alleged relation between nystagmus requirements and aviation performance and specifically, "whether the duration of nystagmus after rotation is an index of the sensitiveness of the mechanisms for appreciating motion and maintaining equilibrium" (28). The reason for thus questioning the nystagmus requirements, beyond the fact that they had never been tested against actual flight performance, was the observation that dancers, circus acrobats, and experienced flyers frequently show little nystagmus. It seemed probable that the degree and duration of nystagmus are reduced by continued activity involving the mechanisms of equilibrium.

The experiment finally arranged was that of rotating six enlisted men 10 times daily (5 times each to right and left) for periods ranging up to 20 days. Four subjects whose records were complete for 16 consecutive days exhibited decreasing average nystagmus times as follows: 24.9, 22.3, 20.6, 16.2, 18.0, 13.6, 13.8, 10.8, 15.9, 13.0, 13.5, 9.6, 8.3, 7.1, 6.8, 5.0, and 6.3. Although their nystagmus times ranged from 22 to 31 seconds before the

experiment, all six subjects eventually fell below the standard of 16 seconds required by the examining board. One finally had no nystagmus at all (111).

Inserted into the report of the Psychology Department in the Air Service Medical (111, pp. 323-329) is an editorial criticism of the above experiment. Moreover, the contrary results of an experiment by otologists are reported. The burden of the criticism is that the six subjects used by the Psychology Department were not tested by otologists to determine normality of vestibular function before entering upon the experiment. Two are reported to have shown "pathology" in later tests (the type of pathology not being indicated) and the other four to have been "lost sight of" before the otologists could examine them. Data are summarized to show that flyers examined by otologists have a normal rather than a reduced nystagmus time. The insert includes, finally, the results of an experiment on 10 subjects each rotated 10 times to the right and 10 times to the left per day for periods ranging up to 46 days. A small reduction of nystagmus time was noted in a few cases, but the duration was again normal in such cases when lenses preventing fixation were placed over the eyes. The insert concludes with the following statement: "The flyer <u>can not</u> practice the fixation of gaze owing to the variability of conditions under which he flies; the subject in the turning chair <u>must</u> fix his gaze accurately after each turning, thereby undergoing a very intensive practice in gaze fixation"[11] (p. 328).

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[11] Dunlap (28, p. 97) says, "I consulted a well-known dancing teacher in New York City, who advised a daily practice period of half an hour prophesying striking results in two weeks." It is not clear whether, in the light of this consultation, the subjects of the Psychology Department were encouraged to fixate. The implication of the editorial insert is that this was so in the psychological experiments but not in experiments of otologists.

Despite this criticism of the psychologists' findings at Mineola, later research (26) supported their results. Moreover, the value of the Barany chair test was also questioned by medical men connected with aviation. Parsons and Segar, on the basis of their investigation of the responses of 100 naval flyers, 35 of whom were rated "good," 44 "average," and 21 "poor," came to the conclusion that there is no relation between Barany chair tests and flying skill (87). In a further study these investigators found a decrease of nystagmus time to a point below 16 seconds in 12 out of a group of 29 flyers who, before training, had a normal duration (88). Moreover, they again pointed out that results with the Barany test have no relation to flight performance.

Ranken (96) found that pilots with over 1000 hours of flying had an average nystagmus time slightly less (20.6 - 21.8 sec.) than pilots with from 100 to 1000 hours of flying (22.6 - 23.0 sec.). The number of cases is not stated, but Ranken says that "several hundreds" were tested. An analysis of data for 100 experienced pilots failed to show any relation between Barany chair reactions and other tests used in selecting pilots (tremor, body-balancing and rod-balancing tests). On the basis of these results and case studies of 100 pilots rated as successful, seven of whom failed to meet American nystagmus requirements, Ranken says, "In the absence of a discovery of present or past signs of symptoms pointing to an aural affection, routine examination by means of the Barany tests is superfluous providing that a thorough medical examination is made" (p. 862).

After analyzing the data on tests of equilibrium, Bauer (14) says:

> We know from actual experience in aviation as well as from the results of the experimental work already cited, that all symptoms derived from stimulation of the labyrinth are subject to decrease in intensity and duration. It is very questionable how much reliability can be placed on the Barany tests in the case of an experienced aviator. The whole subject has been unduly stressed in proportion to its relative value in aviation.
>
> The Barany tests lay too much stress on rotation on the horizontal plane. Perception of changes of motion as found in tipping or tilting are of more value to the aviator. Nystagmus is very variable and not of great significance unless of long duration (over thirty-four seconds) or markedly different in the two directions. There can be no doubt that the reduction of the nystagmus is advantageous (p. 49).

Armstrong (7) writing in 1939 says that Bauer's views have "not been essentially modified" and that "all that remains of the original requirements are those necessary to determine the presence or absence of pathology in the vestibular system."

Other sensory aspects of Form 609 were not subjected to published criticism during the war. In 1929, however, Ickstadt (54) demonstrated that, among those allowed to qualify on the basis of visual tests, there was no relation between visual test results and flight performance. Brimhall (18), in an unpublished manuscript read in 1932, questioned the value of sensory tests for civilian aviators (and the same would apply to Form 609) as set up on the basis of opinion rather than experiment. He summarized data, including Ickstadt's, which question whether there is any relation between results on visual acuity and depth perception tests and flying skill.

## 9. PERSONALITY OBSERVATIONS

During the first World War there was no systematic investigation of personality such as is now attempted by means of standardized personality tests. Nevertheless, each medical examiner in this country and in England was called upon to give his impressions concerning the personality traits of candidates. These impressions were based upon observation made during the regular medical examination and upon biographical data. Participation in athletics was given a great deal of weight. Flack's (32) manometer test in England and free association tests in this country contributed additional data, although the practical use made of this material from the standpoint of personality is not disclosed.

The inadequacy of personality investigations in our own air force during the war is best conveyed by excerpts from records of the Department of Neurology and Psychiatry at Mineola (111, pp. 330-342). Examiners reported on such items as "readiness or disinclination to face difficult situations squarely" and "tendency to dodge critical events in life." Cases were classified A, B, or D in personality. An "A" rating indicated a tendency to stand up under strain; a "B" rating, the possibility of neurotic symptoms developing; and a "D" rating, a poor risk for front line work. Examples of each personality rating were given, apparently for the guidance of the examiner. The following are illustrative:

"A" rating

> Stocky, muscular type; look steady, countenance cheerful, but not overemotional. Activity, good; discipline, good; willing to take chances if necessary. Stability under strain probably excellent. Good judgment.

"B" rating

> Short, well knit; regular features, mobile, expression tense but under control; anxious to understand and please. Manner tense and high-strung. Keen sense of responsibility. Ambitious and keenly interested in his work but inclined to take even trivial events too much to heart. Will do his duty but needs careful watching when he gets to the front. Should be watched for signs of staleness or beginning nervousness, loss of sleep, etc.

"D" rating

> Decidedly self-conscious; slightly aggressive manner; very high strung and overemotional. Lacks normal subjective feeling of fatigue after hard exercise. Talks a great deal and rapidly. Gives the impression of working under great pressure. Is decidedly nervous and lacks voluntary control of expenditure of energy. Reserve store of energy limited. Would probably not stand strain of active service at the front (p. 332).

Toward the end of the war there was an effort, both in this country and in England, to determine the personality requirements for success in aviation. At Mineola the Psychology Department "sought to get an insight into the temperament and personality" of successful flyers by "systematic interviews." As another approach, Dockeray became a flyer and, through his flight experiences and contacts with "hundreds of flying officers, who talked more freely than when they came to the laboratory," attempted to make a job analysis of flying from the standpoint of personality. His conclusions concerning personality were that "no general rule can be laid down. Quiet, methodical men are among the best flyers...The nervous high strung individuals, or those bordering on the temperamental are the least reliable, for although they often become good flyers, they are the most liable to become psychotic under stress" (25, pp. 146-147).

In England, the problem was approached by means of a questionnaire filled out by flyers (98). Each pilot was requested to indicate his age, number of hours of flying, type of machine flown, whether he was married or single, the nature of his civil occupation, whether he believed alcohol necessary, whether he rode a horse, whether he hunted, whether he motored, his favorite amusements, and whether he regarded marriage as a handicap. In addition, he was asked to answer the question, "What are the essential characteristics of a good pilot?" and "What are your views on selection of candidates with regard to temperament, etc.?" The answers of flyers who replied were tabulated. Among essential characteristics, such traits as the following were frequently mentioned: sportsmanship, guts, high-spirit, resolution, initiative, and "hands", meaning ability to get the "feel" of a ship with the hands. With respect to temperament, many of the same things were repeated. Such terms as "guts" and "nerve" appeared frequently. Case studies of good and poor pilots are presented. The study is of doubtful significance, for it was not followed up by development of a questionnaire, rating scale, or the like, which could be applied in selection of pilots and no effort was made, as in the case of more recent research, to determine objectively and quantitatively the significance of each item in predicting flight success or failure.

Paton, MacLake, and Hamilton (89) developed a personality blank for possible use in the selection of aviators. It was divided into three parts, viz., temperament, volition, and intelligence. Under "temperament" were noted the following: "Cheerful or depressed, stable or unstable, self-reliant or submissive, aggressive or pacific, modest or vain, frank or

withholding, tendency to unburden, fond of people or likes to be alone, satisfied with or hypercritical of conditions, punctilious or careless, serious or frivolous, cooperation, sportsmanship, high tension, pleasure in work, irritable." The items listed as "volitional" were: "Energetic or sluggish, quick or slow, impulsive or deliberate, controlled or restless." Under "intelligence" were listed: "Precise or vague, penetrating or superficial, sharp or dull, alert, hesitant or deliberate, resourceful or without initiative, trained or untrained."

The blank was to be filled in by the examining physician. How it was to be interpreted, i. e., which of the traits were to be regarded as desirable in the aviator, is not disclosed. This "personality study" was modified after the war, and from Armstrong's discussion of it, has been used in the examination of candidates for flight training.[12]

Although such personality studies as we have described high-lighted the personality issue, it is doubtful whether they advanced its solution. Much still remains to be done in the substitution of objective methods for the unstandardized clinical approach typical of work in this field during the first World War and continued in the present conflict.

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[12] The revisions were carried out by Longacre (61).

## 10. MEASUREMENT OF PSYCHOLOGICAL FUNCTIONS UNDER LOW OXYGEN TENSION

The chief task of psychologists in the Medical Research Laboratory at Mineola was that of classifying candidates in terms of ability to withstand the effects of low oxygen tension in the Henderson rebreather. This is a metal tank from which the candidate breathes air and into which he also expels it after $CO_2$ has been eliminated. The rebreather provides a means of measuring the rate and depth of breathing and also of determining the oxygen content of the air at any time. Air is inspired and expired through a rubber tube in the candidate's mouth. A clip is fastened to his nose to prevent nasal breathing. Dunlap (27) and Bagby (11) both describe the classification experiments and the results obtained. The methods are described more fully and the apparatus illustrated in Air Service Medical (111, pp. 297-316). Bauer (14) also has illustrations of the apparatus used, including the Henderson rebreather.

All aviators had to be classified quickly; hence, as Dunlap points out, accurate experimental work was hardly possible. Dunlap prefers to call it "clinical" work. Each man was tested but once and that only for a period of about 30 minutes. Oxygen depletion was rapid (7 per cent reached in 25 minutes) and, during the early stages of the work, each man was allowed to reach the fainting stage before being removed from the rebreather. Later, the signs of impending collapse were recognized and the subjects removed while still conscious.

According to Bagby (11) tests used in measuring the effects of low oxygen tension included: visual acuity, auditory acuity, reaction time to upward pressure on the under side of the thigh, steadiness, speed of tapping,

knee jerk, memory (reproduction of consonants, color-number association, recall of positions of lighted lamps within a mass of 49), and attention (serial reaction, addition, card sorting in terms of tactile cues). The results of the preliminary investigation were as follows: (1) tremor, muscular incoordination, and "over-discharge," all becoming more pronounced as oxygen depletion progressed; (2) reduced ability to carry on several tasks simultaneously through "rapid shifting of attention," the subject finally being unable to "concentrate on any task in the normal way;" (3) muscles relaxed, then tensed, and finally twitchy; (4) removal of inhibitions, indicated by uncontrolled emotional outbursts such as breaking the apparatus, winking at the experimenter in a silly manner, and bursting into laughter; (5) ability to "pull oneself together" for performance of brief tasks, followed by desire for rest. Air Service Medical (pp. 312-314) reproduces samples of handwriting which illustrate decreasing legibility with progressive oxygen depletion.

The standard test finally administered to all candidates by means of the "LVN" device, which we have already described (p. 18) comprised three tasks to be performed, one after the other, but in a random order determined beforehand by the experimenter. The number of individuals tested was approximately 7,000. No detailed analysis of results was made. The chief effects of oxygen deficiency were found, according to Dunlap (27) to be "on voluntary sensori-motor coordination and attention." Bagby says that a study of the results by "almost a score of psychological observers" verified the "effect of oxygen depletion as revealed by the preliminary investigation" (11, pp. 108-109). McComas (66) describes the results more fully as follows:

> As a lack of oxygen began to affect the man, the psychologist, who had charge of these reactions, could notice characteristic changes in the time and manner of reactions. These were considered as the results of some loss of ability in attention, or in motor coordination. Such faults as failing to notice a change in the ammeter or not observing a light when it appeared, or ignoring a change in the tone of the motor were rated as attention defects. Slow movements, too slow in reaching the targets, or fumbling, hesitancy and inaccuracy all were counted motor defects.
>
> ...It seemed that the average man showed some defect in both attention and motor control after about fifteen minutes of the test. Then he would frequently regain his abilities and proceed as before, striking his targets as each light appeared, correcting his ammeter, and motor, as he caught the signals. After some twenty-five or thirty minutes the oxygen in the tank would be in the neighborhood of 7 per cent instead of the normal 21 per cent and a frequent result would be a lapse of the attention and an ignoring of the sound of the motor. Usually there would be symtomatic evidences of loss of motor control before this, such as too vigorous thrusts with the stylus and an awkward slide. Whether it was attention, or control of movements, that gave the signal of the approaching collapse it was usually the psychologist who obtained the first information of the subject's inability to continue (pp. 149-150).

McComas also mentions that weakness of the eye muscles, leading to double vision, occurred during rebreather tests, but he does not say whether or not this double vision could have been responsible for any of the other effects described above. It appears, off-hand, that double vision could, at least partially, have been responsible for "motor" inaccuracies such as those observed.

Johnson and Paschal (56) describe an experiment in which 31 subjects transliterated material in accordance with a code while undergoing oxygen depletion. Each letter of the alphabet had its own code letter (P for X, X for B, etc.) and, as a test card was exposed (D J E A S R N U M U for example), the individual was to transliterate as fast as possible, paying

attention to speed as well as accuracy. The different sets of material to be coded were arranged so as to be of approximately equal difficulty. Responses were printed, the reason being that writing often becomes illegible at advanced states of oxygen depletion. In some cases rebreathing was used from the beginning of practice whereas in others it was started after a certain amount of coding activity had occurred. During the preliminary period, all oxygen consumed by the subject was replaced as consumed.

A record is presented for each subject. These records show oxygen consumption, blood pressure, pulse, respiration, and coding performance. Large individual differences are evident. Where the rate of improvement is rapid, the coding score reaches its upper level quickly and then shows a marked decrement when oxygen is depleted to between 15 and 12 per cent. Some subjects compensate for this disturbance by increased muscular activity. Where such compensation activity is complete, the curve fails to show a decrement. In some instances, compensatory activity is incomplete or absent and the curve drops. One case shows what appears to be overcompensation, the curve actually rising before the end of the test. In some cases the increase in voluntary effort "due to the diminution of apprehension, distraction of surroundings, etc., and the increase of interest - is so great that the performance steadily improves in spite of the deleterious effect of depletion of oxygen, until the subject approaches cardiovascular collapse." Noted in this connection, also, is a "constriction of the field of attention, which facilitates the application of effort exclusively to the task in hand" (p. 197). In general, these results "indicate that the simpler sensori-motor reflexes, as a rule, do not exhibit noticeable impairment until deterioration

of the more highly organized responses has reached an advanced stage" (p. 232). Some instances are reported, however, of inability to form a letter or even to put the pencil to the paper when, apparently, the subject was still attending to the material to be coded.

The low pressure chamber was in use at the same time as tests with Henderson's rebreather were being carried out. However, except for a few incidental observations, nothing of a psychological nature was done in it. Some of these incidental observations, samples of handwriting taken at different "altitudes" up to 20,000 feet, and his own experiences while in the low pressure chamber are described by McComas. Dimming of vision at high altitudes is especially noted (65, 66).

Although the English studied altitude effects during the war, they did not, until the end, use anything akin to the rebreather or low pressure tank. Their tests were made before and after altitude flights with and without administration of oxygen. The only directly psychological measurements involved were with the dotting and tremor tests already described. According to Birley (17), however, Flack's (32) manometer test, which was used in this work, yields a measure of such psychological functions as "volition" and "temperament." This test requires the subject, with nose clipped, to blow a column of mercury to 40 mm. and hold it at this level as long as possible. Under normal conditions, the average time is between 50 and 60 seconds. Results of the above-mentioned tests, as far as they applied to altitude effects, suggest a performance decrement after high altitude flight without oxygen and improvement in performance after flight with oxygen. However, the poor control of altitude conditions, the small number of subjects

involved, and the failure to consider low pressure effects accompanying increases in altitude, make these early English tests of little consequence. There was no attempt to classify candidates on the basis of altitude effects as was done in the United States. Emphasis was solely upon determining the fitness of flyers subjected to deficient amounts of oxygen.

In the Atmospheric Depression Laboratory at Saint-Cyr, Garsaux (36) investigated the effect on visual and auditory reaction times of altitudes ranging from 1000 to 6000 meters. He reports that until an altitude of 3500 meters was reached, there was no effect upon reaction time, but that, above this level, reactions became slower and more variable. When oxygen was inhaled, however, the time and variability of reactions were normal. Neither the specific techniques used nor the number of subjects involved are indicated.

## 11. THE DECLINE AND REVIVAL OF AVIATION PSYCHOLOGY

Research in aviation psychology ceased soon after the first World War ended. By 1920 most of the psychological researches of the War were in print, and sterility had virtually settled on the literature. In the United States, for example, despite the growth of aviation and despite the establishment of a thriving School of Aviation Medicine, psychologists turned their backs on aeronautical research (55). In other countries, too, with few exceptions, research by psychologists in the field of aviation was almost totally discontinued.

The revival of interest in aviation psychology began with the preliminary stages of the present conflict. Many surveys of earlier work in aviation psychology and discussions of underlying theory, together with reports of tests used in pilot selection, appeared around 1935. Selection of military rather than civilian pilots was emphasized.

As the present War approached, however, there came a sharp decrease in publications on aviation psychology, although there is reason to believe that the volume of research was assuming larger proportions than ever before. The situation in other belligerent countries was probably similar to that in the United States today. A program of research in aviation psychology which far exceeds in extent anything ever attempted before in this country is underway, but the detailed outcome of this research will not be known until after the War ends.

Because of the absence of publications, it is impossible to present a complete picture of current research in aviation psychology. Nevertheless, the revival of interest in this field is apparent from publications which

appeared during the last decade.

The renaissance of Italian interest in aviation psychology, if Gemelli's publications (39-44) are any indication, preceded that in other countries by several years. It was not until 1937, however, that Gemelli described anything essentially different from the Italian research of the first World War. He then stressed the "personality as a whole" approach (45) and disparaged exclusive use of tests which measure single operations such, for example, as reaction time, emotion, and attention (46). Similar views were expressed by other Italian psychologists (71, 109).

There was apparently a complete gap in German aviation psychology until Edelman in 1934 and Metz in 1936 described tests for selection of pilots. Edelman (31) stressed reaction time and character analysis. Metz (77), director of the Berlin testing station of the Luftwaffe, emphasized such character traits as will-power, self-discipline, and sense of duty. A paper by Lemke (59) describes the results of an examination of 2000 aviation candidates which were classified into body types (Kretchmer's). He also mentions that reaction time was measured with the d'Arsonval chronoscope and complex coordination with Reid's coordinator. Lemke believes that the complex coordinator is quite valuable as a selective device. Participation in sports is also regarded as important in prediction of aviation skill. Lottig (63) mentions that tests of reaction, attention, and fluency at high altitudes are used in German pilot selection. Reaction time and speed of thought processes have been tested in a centrifuge by Burmeister (19). Schmidt (103) describes altitude effects in the low pressure chamber.

Samtev (102) reports that selection of aircraft pilots in Russia prior to 1933 was based upon susceptibility to altitude effects, vestibular

functions, adjustment on three planes (apparently by means of an apparatus like the Ruggles orientator), speed of reaction for movements like those made in flight, physiological conditions while landing, unfounded anxiety, intelligence, and motor coordination. Later Russian publications concern measures of coordination (5), psycho-technical tests (92), blind flying (93), neuropsychic tests (95), and tests for parachutists (69).

Macewiez, who in 1930 became director of the Polish Psychotechnical Laboratory, reported that aviation candidates in Poland were tested for visual reaction time (d'Arsonval chronoscope), visual memory, attention, complex coordination (Reid's apparatus), and an intelligence test devised by Macewiez but not described (64). Przysiecki (94) discussed the role of sports in development of aviation aptitudes. Work in the U chamber was described by Dybowski (30).

Selection of pilots in France during the last decade was apparently based almost entirely upon medical requirements. Lacker (58) writing in 1937, mentions no original French research except physiological studies of acceleration and altitude effects. He does, however, review psychological work carried out in other countries.

Selection of aviators in Spain was based upon psychomotor tests, personality estimates, physiological reaction to sudden emotion-provoking stimulation, and a biographical questionnaire (8).

The medical examination used in the early and middle thirties to select pilots for the R. A. F. included measurement of complex coordination with Reid's apparatus, holding the breath (Flack's test) and the Barany chair test. The latter was used to test aptitude for acrobatics and was also used

when evidence of abnormal susceptibility to uneven movements appeared. Rebreather tests (bag method) were administered. Bartlett (13) mentions measures of interest, temperament, and character as being used in British selection. Harrower-Erickson urges use of the Rorschach test in pilot selection and shows how profiles based upon results of the test may facilitate its use (50, 51).

Several very stimulating papers on aviation psychology have been published in South America during the period under discussion. In 1932 Julio V. d'Oliveira Esteves, Surgeon Subinspector of the Argentine Navy and Chief of the Medical Service of Naval Aviation began a long series of articles on psychological and medical aspects of aviation. One of his most significant psychological contributions is the suggestion that reaction time should be recorded not only from onset of stimulus to initiation of response but also from initiation to termination of response (82). He has applied this suggestion to the study of aviation candidates (83, 85), and has proposed the measurement of responses to simultaneous psychological and physical tasks in the examination of candidates (84). D'Oliveira Esteves claims that use of his methods has reduced the washout rate in Argentina from an original 5 per cent to zero. It is apparent, however, that much attention is given to each trainee. He is tested frequently and his weaknesses, and suggestions for overcoming them, are discussed with his instructor. Mata (74) describes a "psychometrometer" for use in selection of pilots. In another paper (75) he discusses a multiple-choice apparatus which is placed in the plane to measure reactions during flight. Delucchi and Mata (24) describe a test of attention used in selection of pilots. While the candidate is marking off

certain distances on a row of dots a metronome begins to beat at irregular intervals. Subsequently the candidate must continue to mark the dots and at the same time count metronome beats. Odilon (81) describes the use of profiles based upon reaction time, attention, emotionality, and kinesthetic sensitivity in selection of pilots.

In the United States there was little interest in aviation psychology between the end of the war and 1939. Some studies of high altitude effects were carried out;[13] an improved personality form for use in connection with the medical examination was devised (61), a complex coordinator was developed and tested in relation to success in flight training (72, 73), and criticisms of certain visual tests were voiced (54, 18). Flight surgeons rather than professional psychologists were chiefly responsible for the first three developments, while a psychologist as well as medical men had a hand in the last-mentioned development.

In the United States, at the beginning of 1939, there was no program of psychological research in aviation. By 1941, when the United States entered the present War, a well organized program of aeronautics research was under way, and there were at least 100 psychologists who had obtained direct experience in such research (55). This development is largely traceable to the support given since 1939 to psychological research in aviation by a Federal agency, the Civil Aeronautics Authority.[14]

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[13] Armstrong (7, chapters 16-20). Most of the work mentioned by Armstrong is physiological more than psychological. Much of this work was done at the School of Aviation Medicine by medical men without collaboration of psychologists. McFarland has been a leader in psychological studies of low oxygen tension, but his work was done without specific reference to pilot or aircrew performance. For a brief review of work in this field, see (67).

[14] Now Civil Aeronautics Administration.

In the fall of 1939 this Authority embarked on a program of training 10,000 civilian pilots, chiefly among the undergraduate personnel of American colleges and universities, as part of a wide-scale effort to develop the light plane industry by encouraging private flying. Through the efforts of its Director of Research, Dean R. Brimhall, a fund 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, which established a Committee on Selection and Training of Aircraft Pilots to plan and supervise research. Included in this was an executive subcommittee of psychologists[15] and representatives from Aviation Medicine, civilian flying associations, air-arms of the Services, and commercial air lines.

The program of investigation was originally intended for use in studying and solving personnel problems in civilian flying. Even before the United States entered the War, as the international situation became more critical, the functions of this National Research Council Committee on Selection and Training of Aircraft Pilots were extended, with the consent of the Civil Aeronautics Administration, to cover military as well as civilian aviation.

The research program of this committee naturally included the selection and classification of pilots. However, from the very beginning, the importance of training problems was recognized, and attention directed at once towards the investigation of the learning process and of other factors involved in the acquisition of pilot skill. Rating scale techniques and lithographic and photographic methods of recording were developed, the aim being to procure reliable measures of pilot performance during flight.

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15 Among those who have served on the Executive Subcommittee are Jenkins (J.G.), Liddell, Viteles, (Chairmen) and Bray, Brimhall, Carmichael, Dunlap (J.W.), Flanagan, Johnson, McFarland, Miles, Wendt.

Problems of tension and of fatigue, the effects and treatment of motion sickness, and similar maintenance problems were likewise investigated. Moreover, these problems were studied not alone in the laboratory, but in the cockpit of the plane under actual flight conditions.

Such investigations, conducted by cooperating psychologists under the general direction of the Committee on Selection and Training of Aircraft Pilots, have produced significant findings which are now being employed in connection with the War Effort. These will be considered in a text on Aviation Psychology which the Committee is now preparing for publication.

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## 12. SUMMARY

Aviation psychology had its origin in the first World War and was concerned primarily and almost exclusively with the selection of aircraft pilots. Emphasis was at first upon reaction time and emotion. The simple reaction time tests of French and Italian investigators were soon replaced or supplemented by measures of complex reaction. Italian psychologists led in the development of complex reaction tests carried out in simulated cockpits. In some of these tests the stick and rudder bars replaced simple reaction keys. The complex coordinators found so useful in selection of pilots today may be regarded as further developments of the Italian tests.

Measures of emotional reactions were sought by recording blood pressure, pulse, respiration, tremor and sweating in response to stimuli. There was some use, although apparently not for practical purposes, of blood sugar tests. Free association was used to study emotional attitudes toward aspects of flying.

Tests of intellectual processes covered attention, memory, perception, judgment, and general intelligence. Combinations of psychomotor, emotional, and intellectual tests were found to be better predictors of rated flight performance than were any single tests. However, the criteria of performance during the first World War were themselves of doubtful value.

The chief contributions of psychologists to sensory aspects of selection were their criticisms of existing sensory requirements. They emphasized the need of establishing requirements through adequate job analysis and of providing objective, reliable, and proven instruments for measuring sensory capacity. Psychological research disclosed that the Barany chair tests, as used in World War selection of pilots, were of no value when applied to those who had previously engaged in flight, acrobatics, and other activities calling

for intensive stimulation of the mechanisms of equilibrium. Medical men and psychologists criticized the a priori basis of sensory and perceptual tests and standards and questioned the view that they are basic to flying aptitude.

Personality observations were carried out by interview and questionnaire methods, but the reliability of the procedures used is highly questionable. There were no standardized personality tests.

Psychological functions under low oxygen tension were measured for classification purposes. Complex psychomotor reactions and attention were emphasized in this connection. In general the results indicated a breakdown of complex before simpler sensori-motor processes. However, large individual differences were noted. Some individuals, even when near the point of collapse, "pulled themselves together" and actually improved their performance.

Prior to preliminary stages of the present conflict aviation psychology had suffered decline. However, a widespread revival of interest was apparent by 1935. A review of work in various countries during the last decade shows that psychological methods of selection were almost universally in use. The early part of this period is, however, marked more by theoretical discussion and reviews or adaptations of earlier work than by new research. Only limited information is available concerning recent research on aviation psychology in the belligerent countries.

The program of research sponsored by the Civil Aeronautics Administration, through the N.R.C. Committee on Selection and Training of Aircraft Pilots, which began in 1939, was the first comprehensive and systematic approach to problems of aviation psychology. Among other things, this program broadened the scope of aviation psychology to embrace the training and maintenance of flyers as well as their selection. It also emphasized for the first time the

development of reliable indices of flight performance, research carried out during flight and experiments to determine the actual relation of tests to flight performance.

The chief values of early aviation psychology are (1) that it broke the ground for later investigators and (2) that it showed some avenues which are fruitful and others which are unfruitful. On the positive side, for example, are the Italian studies of reaction time which suggested the value of complex choice reactions in a simulated cockpit. On the negative side are measures of psychological processes which, although they "looked reasonable" were tried out and found practically worthless in selection of aviators. Outstanding among these were the tests of simple reactions and the Barany chair nystagmus and pointing tests.

The chief criticisms of early work in aviation psychology are: (1) its preoccupation with selection to the exclusion of the learning process and other functions affecting flight performance; (2) the neglect of job analysis as a means of determining the exact value of the task performance by pilots; (3) failure to conduct research in the air; (4) absence of trustworthy methods for rating or measuring flight performance so that the value of tests in selecting aviators could be determined; and (5) absence, in most instances, of adequate research aimed at determining how well the tests actually differentiated good and poor prospects for flight training. In so far as tests are concerned, there was too much dependence upon the "reasonableness" of a test, upon what is sometimes called "face validity," and a parallel failure to determine experimentally its actual value in selecting flyers. Use of the Barany chair test and of simple reaction time tests are good illustrations of this tendency. Nevertheless, limited in related experience, limited by

inadequacies of statistical methodology (55), and limited in opportunities for research in the air, psychologists made significant contributions to aviation psychology during the first World War. It is to be regretted that psychological research virtually stopped with the end of the War to be renewed only as the present conflict approached.

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