PRELIMINARY EXPERIMENTAL INVESTIGATIONS OF "TENSION" AS A DETERMINANT OF PERFORMANCE IN FLIGHT TRAINING

by

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

January 1946

CIVIL AERONAUTICS ADMINISTRATION
Division of Research
Report No. 54
Washington, D. C.

National Research Council

Committee on Selection and Training of Aircraft Pilots

Executive Subcommittee

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LETTER OF TRANSMITTAL

NATIONAL RESEARCH COUNCIL

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

Committee on Selection and Training of Aircraft Pilots

January 10, 1946

Dr. Dean R. Brimhall
Asst. to Administrator for Research
Civil Aeronautics Administration
Room 5835, Commerce Building
Washington 25, D. C.

Dear Dr. Brimhall:

Attached is a report entitled Preliminary Experimental Investigations of "Tension" as a Determinant of Performance in Flight Training, by A. C. Williams, Jr., J. W. Macmillan, and J. G. Jenkins. This is submitted by the Committee on Selection and Training of Aircraft Pilots with the recommendation that it be included in the series of technical reports being issued by the Division of Research, Civil Aeronautics Administration.

As indicated in the report, the study was undertaken because of widespread concern on the part of those engaged in training pilots with the presumably adverse effect of "tension" upon success in learning to fly and on flight performance. As stated by the authors, the immediate outcomes of the experimental program are "at best suggestive and indeterminate," partly because of personnel and other difficulties experienced in the conduct of research. Attention is drawn to the conviction, stated in the Foreword, that "the definition of 'tension' which emerges at the end is far more important than the demonstration that certain components of 'tension' may or may not be covariable with other elements in the flight training situation."

Cordially yours,

M S Viteles

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

MSV:pd

FOREWORD

All of the research personnel originally connected with this project are on active duty in the Armed Services with tours of active duty already from three to five years in length. There is no better way of explaining why this report is submitted in mid-1945 on a research project that was conceived in 1939 and executed during the next three years.

Calls to active duty are sudden and unforeseeable events. Experimental subjects disappear overnight and research personnel is called away without any opportunity to put data and other materials in proper order. What would have been a well organized research program thus becomes a disjointed affair to be rounded out in so far as military exigencies permit.

The two primary experimenters in this project have been on special duties which have long kept them outside the continental limits. It has fallen to the lot of the undersigned to prepare this report, despite the fact that, when the research was in progress, administrative duties for the Committee on Selection and Training of Aircraft Pilots allowed him but little contact with the actual experimentation. He has been able to work on the report only as a spare-time activity during a period of active military service and without significant opportunity to consult with the original experimenters.

The outcome, as presented herewith, is a summary report, rather than a detailed account of the minute steps by which the research was accomplished. It seeks to lay a background for later research, rather than to document in detail findings which are at best suggestive and indeterminate. The report is written with the conviction that the definition of "tension" which emerges at the end is far more important than the demonstration that certain components of "tension" may or may not be covariable with other elements in the flight training situation.

The undersigned did little more than to conceive the original approach to the problem, offer occasional critical review, and write this report. The actual experimental work was under the direct supervision of Dr. A. C. Williams, Jr. (now Lieutenant, USNR). He was also directly responsible for the statistical analysis of the results. During much of the time he shared the responsibility for directing the research with Dr. J. W. Macmillan (now Lieutenant, USNR). Faithful and insightful assistance was supplied by graduate students at the University of Maryland, including J. T. Fontaine, M. D. Kaplon, J. S. Thatcher, (all three of whom are now on active duty in the Armed Services). H. G. Phillips and L. P. Guest also had a hand in the extensive analysis of records involved in this project.

If credit accrues to any part of the report, let it be given altogether to Lt. Williams and those who worked with him. If there are obvious shortcomings, let them be ascribed to the undersigned as faults of direction or reporting. The important thing is to lay the basis for research yet to come.

J. G. Jenkins
Captain, H(S), USNR

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SUMMARY

The findings in this report describe the outcomes of research designed to determine the effects of tension on learning to fly. These studies, conducted at the University of Maryland under the auspices of the Committee on Selection and Training of Aircraft Pilots, are divided into four experimental phases, covering a period of more than three years. A subsidiary project involving a further analysis of records obtained from the Fries Flight Analyzers in the Maryland Tension Study is presented in Appendix A.

The First Experimental Phase was designed to obtain records of grip tension from the control stick on 10 students training in the Primary civilian Pilot Training Course. Before the work of the first phase was completed, however, 29 students had been used as subjects.

In order to get objective records of flight competence which could be used as a criterion against which to validate the tension data, a Fries Flight Analyzer was installed in a Piper Cub training plane and modified to record grip tension on the control stick, airspeed, altitude, vertical acceleration, movements of aileron, rudder, and elevator; and signals made by the instructor. To quantify the records of grip tension they were categorized as "a" (excursions of 0/10 to 1/10 inch), "b" (excursions of 1/10 to 2/10 inch), "c" (excursions of 2/10 to 3/10 inch), and "d" (excursions of more than 3/10 inch.

Usable records were obtained on 366 instructional periods, including 1351 scorable take-offs and 1354 scorable landings. Of the scorable take-offs, 48.5 per cent were accompanied by some category of grip tension, while of the scorable landings 72 per cent were accompanied by some recorded category of grip tension. All students exhibited a higher percentage of recorded tension in landings than in take-offs.

When a stage by stage comparison of grip tension was made it was observed that it reached its highest values during the solo stage. It was found that the goodness of flight performance could not be measured directly from the flight analyzer records, and it was decided to have the instructor compare each student with every other student and employ the results of these comparisons as a basis for placing the 10 students in rank order. A comparison between percentages of landings accompanied by excessive grip tension and rated competence for 29 subjects failed to give any clear-cut evidence that the top rated students tended to be less tense during this maneuver than the students ranked as less competent.

The results of the First Experimental Phase suggested that grip tension was too localized an index of tension and that efforts should be dirrected to search for other bodily reverberations of this condition. As a consequence, part of the Second Experimental Phase was concerned with the development of apparatus for obtaining other tension indices. With the new equipment it was possible to get a record on the flight analyzer of airspeed, grip tension, myo-voltmeter readings, cardiotachometer readings, pneumographic tracings, signals from Kelly's foot pedal recorder, and ma-

neuver code from the instructor. Much of the experimental work was devoted to the calibrating of the equipment. Many trials were run off with A. C. Williams as instructor and graduate students or staff members serving as subjects. In the course of these trials it was possible to adjust the performance of the various instruments to what were seen as the requirements of the Third Experimental Phase.

In the Third Experimental Phase measurements of tension were obtained during four series of specially designed flights. Each flight consisted of four take-offs and landings, four series of steep turns, and one simulated emergency. After each flight the instructor prepared a description of the flight, including comments on the apparent tenseness of the student, his flight aptitude, and his errors. He also rated each student in comparison with others as to general flying ability.

At least one record apiece was obtained for each of 29 students. However, because of certain unforeseeable events at the time of the research, the results of Phase 3 are not complete.

The findings indicated: (1) there appears to be no evidence of significant covariability of any of the tension indicators as against ratings on flight competence or the ratings on tenseness assigned by instructors, (2) an analysis of variance of myo-voltmeter readings during landings indicated that inter-individual variation was the major source of variability in the myo-voltmeter data, and (3) extended treatment of the pneumographic recordings during the basic maneuvers chosen for the study showed high inter-individual variability. Means for take-offs and landings were accompanied by the larger increases in respiration.

The outcomes of this experimental phase suggested that the conception of tension was in need of restatement, and it was decided to go to the instructors to see if they could tell what they meant when they spoke of a student as being "tense." An attempt was made, in effect, to obtain from the instructors a redefinition of the basic problem. This is reported as Phase 4 of the project.

In the Fourth Experimental Phase the basic problem of redefinition was approached through a set of general questions directed to the flight instructors. An analysis of their responses showed that 33 of them used the term "tension" only to describe a student whose muscles were tense, while 29 stated that tension might be either mental, physical, or both. A further check was made of the difference between the two groups of instructors, i.e., those who spoke only of physical tension and those who stated that tension might be physical or mental. The 17 most common reasons listed by the two groups when placed in a contingency table (2 x 17) suggested a difference no greater than that to be expected in chance fluctuations of random sampling (p value was .52). Direct inquiry appeared to indicate that the term "tension" meant many things to many different individuals.

The subsidiary project described in Appendix A was designed to study the usefulness of Fries Flight Analyzers Nos. 643 and 644 for differentiating good and poor students on the basis of records made with this equipment. Take-offs, landings, and steep 8's were chosen as the maneuvers to furnish the potential criterion data, and records were collected on 29 Civilian Pilot Training students from the Spring of 1940 to the Spring of 1941. Clear-cut relationships between flight analyzer data and rated flying ability were not observed for any of the maneuvers.

PRELIMINARY EXPERIMENTAL INVESTIGATIONS OF "TENSION" AS A DETERMINANT OF PERFORMANCE IN FLIGHT TRAINING

INTRODUCTION

The folklore of aviation training abounds with statements which point to tension as an important enemy of success in learning to become a good and skillful pilot. As examples of extreme tenseness, there are many tales of students who have "frozen the controls," requiring a therapeutic application of the fire extinguisher or other convenient weapon by the instructor. In lesser degrees, mentions of the harmful effects of tension are to be found in such varied sources as the flight jackets of failing students, the conversation of veteran instructors, and the remarks of experienced flight surgeons. It appears to be generally agreed among the air minded that the student who is tense in the air thereby defines himself as a poor prospect for profit from flight instruction.

This state of affairs was known to the Committee on Selection and Training of Aircraft Pilots at the time of its formation; and it was further confirmed by all early inquiries directed along these lines. The problem laid before the Committee seemed at the outset a very simple one indeed. Those sophisticated in aviation agreed that tension was hostile to flight success. To verify this by application of quantitative methods seemed to involve three, and only three, basic steps:

1. To measure objectively the amount of tension present in an adequate number of students during flight training.

2. To obtain satisfactory measures of their progress through training and their general competence as pilots.

3. To obtain some measure of the covariability of these two measures.

The possible outcomes were apparently foreseeable. If a high, negative correlation were to be obtained between measured tension and measured flight competence, the folklore concept of tension would have been vindicated. In this case, one could advise using a measure of tension as an early means of selecting pilot material; and one could also look about for ways of reducing tension. A second possibility was that a negligible relationship would be found. Such a discovery would be enough to show that there was no apparent relationship between tension and flight success; and instructors could be urged to disregard signs of tenseness in students as non-significant. Finally, it was possible that a positive relationship would be found of sufficient size to indicate that high tension and success actually went together. This would mean that the folklore was the reverse of the demonstrated truth and it would then be necessary to re-educate instructors to regard tenseness as a favorable sign in their students.

It did not occur to the project sponsors or to the Committee that there was any real doubt as to what the term "tension" or "tenseness" meant. Only after much work had been done and only after some hundreds of records had been made of muscular tension during flight, did it become apparent that a considerable variety of uncorrelated symptoms had been arbitrarily forced into a single category by those who used the term "tension." Only in the latter stages of the project, then, did the investigators reach a stage of defining basic terms which logically should have been the proper starting point.

The basic reason for this situation is easy to find. The sponsors of the project came to the field of aviation with a knowledge of much of the recent work done by psychologists on the effects of muscular tension. They were aware of researches reported by Davis,[1] Freeman,[2] and Bills,[3] and others on the effects of muscular tension upon output in various skilled activities. They were also aware of publications by Jacobson[4] in which he described the therapeutic use of progressive relaxation in eliminating certain non-hygienic effects of excessive muscular tenseness.

Accepting "tension" as meaning muscular tension in aviation as it did in the psychological laboratory, the basic problem appeared to be simplicity itself, and the original research proposal offered to the Committee was accordingly very simple. It was proposed that the top of the control stick be encased in a rubber bulb, leading to some sort of pneumatic recorder. High tension would lead to considerable pressure on the bulb which would then be recorded; and lower degrees of muscular tension would yield progressively smaller amounts of recording. Recorded tension would then be compared with flight performance and the interrelationship mathematically expressed. There was nothing novel in this proposal except its application to the flight situation, for the basic technique had been used by Morgan[5] and others in previously reported studies in typewriting and

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[1]Davis, R. C. The relation of certain muscle action potentials to "mental work." Ind. Univ. Publ. Sci. Serv., 1937, No. 5.

Davis, R. C. The relation of muscle action potentials to difficulty and frustration. J. exp. Psychol., 1938, 23, 141-158.

Davis, R. C. Patterns of muscular activity during mental work and their constancy. J. exp. Psychol, 1939, 24, 451-465.

[2]Freeman, G. L. The facilitative and inhibitory effects of muscular tension upon performance. Amer. J. Psychol., 1933, 45, 17-52.

Freeman, G. L. The optimal hours of "anticipatory tensions" in muscular work. J. exp. Psychol., 1937, 21, 554-564.

Freeman, G. L. The optimal muscular tensions for various performances. Amer. J. Psychol., 1938, 51-146-150.

[3]Bills, A. G. The influence of muscular tens'on on the efficiency of mental work. Amer. J. Psychol., 1927, 38, 227-251.

[4]Jacobson, E. Progressive relaxation. Chicago: Univ. Chicago Press, 1929.

[5]Morgan, J. J. B. The overcoming of distraction and other resistances. Arch. Psychol., N. Y., 1916, 35.

other simple skills.

Moreover, just as the study was about to get under way, the sponsors of the project were informed that it would be possible to obtain an apparatus which, they were told, would give an objective measure of flight performance. This made the outlook even more promising. If they could obtain objective measures of how well student pilots actually flew, they would be freed of dependence upon such subjectively colored criteria as judgments of instructors, pass-fail records, and entries in flight jackets. The rubber bulb, it appeared, would give them quantitative measures of "tension"; the flight recorder, they were told, would give them quantitative measures of flight performance; and, the only task left would be a study of the interrelations of these two quantitative and objective measures.

If the facts had justified the postulates stated above, this might well have been a definitive report. The fact that it is only a report of exploratory research adequately reflects the sharp failure of the two variables to fall into the neatly quantified series which the sponsors were led to anticipate.

It may be simplest to summarize the current state of affairs by contrasting theory and fact. Theory, in this case, is nothing more than the postulates upon which the experimental design was based. Fact then becomes an explanation of what was actually learned as the research was pushed along through more than one thousand training flights.

Theory	Fact
1. When instructors spoke of "tension," they referred to muscular tension.	When instructors spoke of "tension," they were referring to any one or more of a half-dozen disparate and other unrelated sets of symptoms or causes of symptoms. Excessive muscular output, at best, was only one of these. To measure muscular tension told little or nothing about many, if not most, of the students whom instructors would describe as "tense."
2. The flight recorder would give an objective record of how well a given student flew.	Flight recorders provide information on only certain aspects of pilot proficiency, viz., those pertaining primarily to "maneuver-doing." In addition, the recorders available at the time of the research were limited as to type and range of data recorded, and techniques for interpretation of the recorded data in terms of flight proficiency were as yet undeveloped.

In a word, actual investigation was to show that we would be able to get at only one aspect of "tension" through this project as outlined. It was also to show that the simple, objective criterion of flight competence was a pious hope rather than an obtainable reality. Thus, since neither of the two basic variables proved to be immediately available for measurement, this report cannot be a definitive statement of their interrelationship.

To say all of what has been said above is not to state that the project yielded no useful outcome. It is rather to point out that the outcome was much less ambitious in scope and less definitive in nature than had been anticipated. Useful apparatus has been developed; and the limitations as well as the virtues of this apparatus can be described. An initial attack has been made on the problem of learning what flight instructors mean by the term "tension." In so far as tension is taken to mean excessive muscular output of certain specific muscles, its relationships to certain variables in flight performance have been studied and can be described in these pages. It is unfortunate that the project had to be suspended at this stage, due to the enrollment of all the research personnel in one or the other of the Armed Services. Even such a curtailment, however, does not deprive this report of what may be its major usefulness -- that of pointing the way to further research, both by indicating leads that have been tried and found sterile, and by pointing out leads that seem amply to warrant further study.

FIRST EXPERIMENTAL PHASE (1939-1941)
Excessive Muscular Tension vs. Level of Performance in Training

The design of the first phase of the experiment was dictated in part by the necessity of conducting the research without interferring with the flight training of the available subjects. Arrangements were made with the operator of the airport at College Park, Maryland, to install the necessary equipment in a Piper Cub primary training plane, with the understanding that a specified group of students would, in so far as possible, receive all of their training flights in this plane. An effort was thus made to obtain recordings on all flights made by this group of students from their first dual indoctrination hop to the final flight examination for a private pilot license.

It was planned to follow ten students through the entire Primary Civilian Pilot Training Course. The design provided that recordings should be made of their grip upon the control stick during all of the flights they would make and that their degree of grip pressure should ultimately be correlated against various criteria of flight competence that might become available. On the basis of available literature describing the Friez Flight Analyzer,[6] it was hoped that recordings of

[6]An early description of this equipment is contained in a folder ussued by the Julian P. Friez Co., Baltimore, Md., entitled Instructions for installation, operation, and care of the Friez Flight Analyzers, Types 643 and 644. A subsidiary project utilizing this equipment is described in Appendix A.

the attitude of the airplane during these ordinary training flights would provide an objective record of flight competence which would serve as the primary criterion.[7]

After considerable delay, a Friez Flight Analyzer was obtained and installed in a training plane. A slight modification was introduced into this apparatus to permit the recording of grip tension on the same roll of paper which carried the records produced by instruments designed to reflect the attitude of the airplane. As finally installed, the Analyzer presumptively furnished continuous indications of (a) grip tension on the control stick, (b) airspeed, (c) altitude, (d) vertical acceleration, (e) movements of the ailerons, rudder, and elevator, and (f) signals made by the instructor (on-off contacts only).

Grip tension was recorded by substituting for the handle of a conventional Cub control stick a stout piece of rubber hose, hermetically sealed and connected with the sylphons in the Analyzer. The rubber hole was secured from the inside at the top by a metal tube running inside to the control stick below. This prevented bending when normal movements of the stick were made in controlling the plane. The stiffness of the hose was such that pressure from any one direction would not compress it; hence no record was made when normal movements of the stick were employed. When, however, the hose was squeezed from any two directions simultaneously, as in any tightening of the grip on the stick itself, a record was made on the recording drum. Routine CPT instruction lays emphasis on maintaining a light contact between the control stick and the fingers. Accordingly, any genuine squeezing of the stick could appropriately be regarded as a true indicator of muscle tension and would not have to be dismissed as an artifact incident to the proper handling of the controls.[8]

With the plane thus equipped, the initial ten students were followed through the course, with recordings being made of all flights in which it was possible for them to use the experimental plane. All ten of these students succeeded in completing the course and all of them received their private pilot license. There was reason to believe that they represented a considerable spread of ability, in terms of light-plane piloting performance.

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[7]Editor's Note. Dependence upon characteristic patterns in graphic records for the identification of separate maneuvers is made unnecessary through the use of standard flights which specify the nature and order of maneuvers. At the time of this research such flights, now in frequent use in Committee research, were in the process of development by the University of Pennsylvania project.

[8]Since the system was airtight, the recordings suffered because an altitude effect was produced. This resulted in a baseline which shifted with the altitude of the plane. Since this was relatively smooth and predictable, however, it did not seriously interfere with the interpretation of the records.

Inspection of their records, on completion of the training course, showed immediately that:

1. Grip tension did occur during flight.

2. It was not necessary concomitant of the act of piloting since some of the students did not exhibit grip tension and since those who did exhibit it did not do so all of the time.

3. No student ever showed grip tension continuously throughout any flight.

Inspection of the 366 records obtained on the first ten students[9] showed that the maneuvers of take-off and landing accounted for more than 90% of the manifestations of grip tension. Identification of the maneuvers responsible for the remainder of such manifestations of tension proved a difficult task. It was found possible to identify on the records, those maneuvers which involved steep turns, but shallow turns could not be identified. Even with the identifiable maneuvers, the record showed only that the maneuver had been performed; it did not give sufficient evidence for the investigator to say how well it had been performed.[10] Thus all relationships between recorded tension and the quality of flight performance had to be based upon ratings assigned by instructors.

Any squeezing of the control stick produced a distinct local excursion of the recording pen. This made it possible to undertake a quantitative evaluation of the amount of tension during any identifiable maneuver or during any given flight. The most workable system of attack on the quantifying of the tension records was as follows. The chart paper used on the recorder was ruled off in tenth-inch squares. By counting the number of squares enclosed by the base line on one side and the curve of the pen excursion on the other, an estimate of the area of the excursion could be obtained. A distinction was made between the extent of the excursion (representing the amount of tension) and the duration of the excursion (representing the length of time the force was effective). Experience with the scoring system showed that extent could be most usefully classified according to the following scheme which is employed throughout this section of the report, i.e., the small letter a represents excursions of 0/10 inch to 1/10 inch; b, excursions of 1/10 to 2/10 inch; c, excursions of 2/10 to 3/10 inch; and d, excursions of more than 3/10 inch.

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[9]Certain flights went unrecorded for such reasons as apparatus failure, use of some other airplane, and the like.

[10]Editor's Note. A by-product of the investigation was the study of the relative amount of time spent in the air and on the ground during flight instruction. The findings are reported in: NRC Committee on Selection and Training of Aircraft Pilots. Investigations of the relative amount of time spent on the ground and in the air by Civilian Pilot Training students. Washington, D. C.: CAA Division of Research, Report No. 43, March 1945.

This system makes it possible to describe any given excursion of the pen in terms of a given category of extent for a stated period of time. Thus, a student who squeezed the stick during a landing might be scored in our records as "2a, 1b, 2c, 1d." This would mean that for 2/10 inch on the time line, the student squeezed only with force "a" as described above, then increased his grip to force "b" for 1/10 inch on the time line, going from there into successively heavier grips on the stick for the durations indicated by the numbers. Since the speed of recording was constant, this statement could be rephrased in terms of seconds when and if the occasion demanded.

Data sheets were made up and all take-offs and landings for all ten students during each of the 366 recorded flights were scored in the above fashion. The raw data could then be treated in any one of a number of fashions. A numerical value could be obtained by weighting the categories and summing them up for each occurrence of tension. Likewise, a qualitative index could be obtained by classifying each occurrence of recorded tension according to the largest category present, disregarding duration. Combinations of these two schemes were also tried out.

Criterion Data. It had been hoped originally that goodness of flight performance could be measured directly from the Flight Analyzer records. Due to the complete impossibility of identifying most maneuvers, however, such measurements could not be made. Indeed, the sole value of the Flight Analyzer at this point proved to be that of labeling certain basic maneuvers on the tension record. This made it necessary to employ some other means of ranking the students in terms of their flight performance. Experience at the University of Maryland and elsewhere[11] had shown that the flight grades assigned by the instructors could not satisfactorily be used as criteria in view of evidence that (a) they were low in reliability and (b) they had no real spread.

In the face of this situation, it was decided to use paired comparison ratings, given by the instructor who had instructed all ten of the students in this group. The instructor was asked to compare each student with every other student; and the results thus obtained were used to arrange the students in rank order. (The instructor, indeed, expressed surprise at the outcome of what appeared to him a complicated procedure, stating that it had arranged the students in an order he would judge to be correct.)

Results. Usable records were obtained on 366 instructional periods, including 1351 scorable take-offs and 1354 scorable landings. Of the scorable take-offs, 48.5% were accompanied by some category of grip tension (see Table 1). Of the scorable landings 72.0% were accompanied by some recorded category of grip tension. The wide range of variability

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[11] Johnson, H. M., and Boots, M. L. Analysis of ratings in the preliminary phase of the C.A.A. Training Program. Washington, D. C.: CAA Division of Research, Report No. 21, October 1943.

in incidence of grip tension may be illustrated by the following data, based on analysis of take-off records.

TABLE 1

RELATIVE INCIDENCE OF TENSION AMONG 10 CIVILIAN PILOT TRAINING STUDENTS ON TAKE-OFFS

Student	Take-offs	Per cent Showing Recorded Grip Tension
A	122	42%
B	154	12%
C	134	60%
D	154	81%
E	128	28%
F	130	69%
G	123	11%
H	165	63%
I	118	45%
J	123	67%
Total	1351	48.5%

A glance at the table arouses some conviction that there are real individual differences in recorded grip tension. This receives direct confirmation from a statistical analysis of the data shown in the Table. (To reach the 1% level of assurance, differences between the percentages given in the Table must exceed 11%-16% for the numbers of take-offs represented. The number of percentage-differences reaching this level is certainly adequate to justify the statement that differences in grip tension on take-off have been found to exist.) Reference to the data on landings shows a similarly large range (22%-89%) but here it should be noted that only two of the students fell outside of the area between 72% and 89%. All students exhibited a higher percentage of recorded tension in landings than they did in take-offs.

There was reason to believe that grip tension varied with the stage of training, and accordingly a stage-by-stage comparison was made. This comparison is shown in Table 2.

There is an interesting suggestion of a tendency for recorded grip tension to reach its highest values during the solo stage. Such a finding is in line with the folklore of the field which represents the newly soloed student as much more on the qui vive than he was when an instructor was along or than he becomes later when aeronautical surroundings have become more familiar.

These data offered encouraging evidence that recorded grip tension was significantly variable; and they suggested that one might hope to determine some of the conditions of its variability. The next step was to determine whether it would be possible to detect any systematic variability of grip tension with the instructor's appraisal of flight competence.

TABLE 2

INCIDENCE OF TENSION IN LANDINGS AND TAKE-OFFS DURING EACH STAGE OF TRAINING

Stage	Per cent Take-offs with Recorded Tension	Per cent Landings with Recorded Tension
Stage A (pre-solo)	56%	76%
Stage B (solo)	61%	96%
Stage C (precision)	40%	78%
Stage D (cross country)	45%	57%

It will be recalled that the students had been arranged in a rank order of rated flight competence through the medium of a paired comparison. This might properly be regarded as a "criterion-by-default," employed only because the limitations of the flight recorder deprived us of more objective, reliable measures. The basic data are shown in Table 3.

TABLE 3

RELATION OF FREQUENCY OF LANDINGS WITH EXCESS GRIP TENSION (c or d levels) TO RATED FLIGHT COMPETENCE

Students as Ranked by Instructor	Landings with less than "excessive" tension (0, a, or b)*		Landing with "excessive" grip tension (c or d)	
	N		N	
A	109	88%	15	12%
B	154	99%	2	1%
C	112	82%	24	18%
D	129	84%	24	16%
E	75	58%	54	42%
F	112	87%	17	13%
G	79	66%	41	34%
H	62	34%	109	66%
I	102	87%	15	13%
J	48	39%	75	61%

*See page 6 for definitions of recorded tension levels (0, a, b, c, d). Note also that Table 3 deals with excess levels of tension, where Tables 1 and 2 dealt with all recorded tension.

While the results are certainly not clear-cut, there is an apparent tendency for them to follow the lines predicted by aeronautical folklore. Granting notable exceptions in the case of Students F, I, and possibly A, the less frequent occurrences of recorded extreme tension tend to accumulate at the upper end of the competence ratings, with the higher percentages accumulating at the lower end. For those who may be willing to accept rank order correlations on the basis of ten cases (including one tie) it may be said that rho here is equal to + .62, with a standard error of about half that amount. It may be added that no way of fractionating the data gave any statistically significant result in terms of trying to nail down as definitive the tendency that appears in Table 3.

Attention was turned to the analysis of tension on take-offs, in the hope that this might yield more dependable signs of any covariability between grip tension and flight competence. Although some 1300 take-off records were measured and analyzed, the number found to have any traces of excessive tension was so small as to preclude any significant treatment. It should be noted that 5 of the 10 subjects showed no cases of recorded excess grip tension on take-off and that the only two subjects showing any considerable frequency of excess tension were those rated respectively fourth and tenth in flight competence.

The results were, then, not definitive; but the Committee agreed that a way was available to establish more reliably the relationship between grip tension and flight competence. The luxury of making a re-check on a large population of flight students was clearly out of the question. Even to follow ten students through sample flights involved an exorbitant amount of man hours expended on the air field where the records were collected and in the computing room where they were subjected to painstaking measurement and analysis. To follow, say, 50 or 100, would have run into large budgetary involvements.

It was possible, however, to take advantage of the concept of combined probabilities and to determine in this way whether a stable relationship existed. We had obtained a reasonably high rank order coefficient in our first group in checking grip tension on landings. If a coefficient of similar proportions and sign were to be obtained in a second group, the probability of this successive occurrence being due to chance alone would be measurably remote. And, if it were to be obtained in a third successive sample of ten, all ordinary considerations of probability would certainly have been satisfied. The reader will be aware that economy has often demanded this approach in dealing with researches where expense made the use of large experimental groups impractical.

The Committee accepted the proposal for the employment of two successive groups of ten students each as re-check populations for the finding on the earlier group. Accordingly, a second group of ten students was rounded up and the usual recordings were made as they progressed through their flight training.

Soon after the start of the second group, one of the students in this group washed out for failure to make satisfactory progress. It was then too late to secure an untrained replacement, so the remaining group of nine was accepted as the experimental population and followed through specified sample flights for the balance of the program. Table 4 indicates the percentages of landings with excessive grip tension for this group.

TABLE 4

RELATION FOR THE SECOND GROUP BETWEEN THE PERCENTAGES OF LANDINGS ACCOMPANIED BY EXCESSIVE GRIP TENSION AND RATED COMPETENCE

Students as Ranked by Instructor	Landings with less than Excessive Grip Tension	Landings with Excessive Grip Tension
A	82%	18%
B	79%	21%
C	15%	85%
D	39%	61%
E	98%	2%
F	100%	0%
G	91%	9%
H	67%	33%
I	78%	22%

The positive relationship shown for the first group has disappeared in the second group. The data form essentially a zero relationship (rho being -.08) with the two highest percentages of recorded tension occurring in the men rated third and fourth, and with the lowest percentages falling in the middle of the distribution. There is not even the slightest approach to statistically significant interpretation of these results.

Work had been begun on a third group of ten students, however, and it seemed advisable to carry this through, regardless of the fact that the above data rendered any definitive (or even indicative) findings highly improbable. Table 5 shows the results of analyzing the 540 interpretable landing records available for the third group.

Again the results were completely indeterminate, with the curious circumstance that two of the highest degrees of tension were found in the top rated four students. The results again exhibit a complete lack of statistical significance, with rho (in the presence of three ties) indicated as -.56.

Summary. Twenty-nine students had been run through this first phase and a prodigious amount of record measuring had been done, all to the end result that no significant difference or suggestion of a difference had been found. The folklore belief in the negative effects of tension had been neither confirmed nor negated. The problem, in other words, had proved not to be susceptible of solution by the simple attack indicated as satisfactory by a review of the literature of flight training.

TABLE 5

RELATIONSHIP FOR THE THIRD GROUP BETWEEN THE INCIDENCE OF EXCESSIVE GRIP TENSION IN LANDING AND RATINGS BY INSTRUCTOR

Students as Ranked by Instructor	Landings with less than Excessive Grip Tension	Landings with Excessive Grip Tension
A	61%	39%
B	31%	69%
C	74%	26%
D	23%	77%
E	90%	10%
F	54%	46%
G	72%	28%
H	69%	31%
I	90%	10%
J	90%	10%

SECOND EXPERIMENTAL PHASE (1941-1942)
Development and Field Testing of Improved Methods for Recording Physiological Indicators of Tension

The first experimental phase had demonstrated little more than that tension did occur in varying amounts in students and that it was most easily detectable during landings. The positive demonstrations resulting from more than two years of exploration can be summarized, without undue abbreviation, in that single statement. The negative outcome included at least the following:

1. It is a great handicap to be compelled to carry out researches as subsidiary to training. The sponsor would be repaid if he were to establish means of making the research primary and the training secondary.

2. The Friez Flight Analyzer proved incapable of supplying the anticipated objective measure of flight performance. At the most, it was capable of providing an indication that certain maneuvers were done; but it did not indicate how well they were done.

3. It is uneconomical, impractical, and unnecessary to attempt to record all the flights made in a training course. For purposes of studying tension, selected flights spaced throughout the course, could be expected to give adequate information for all our experimental needs.

4. The ordinary Civilian Pilot Training instructor could not be relied upon to signal start and end of maneuvers or to indicate that certain other events had occurred. If it was necessary to

obtain such information, either new types of objective recorders would have to be developed or specially trained research personnel would have to be employed as instructors.

Basic Postulates of the Second Experimental Phase. In planning for Phase 2, it was realized that the non-definitive results of Phase 1 were susceptible of various interpretations. Our failure to find any covariability between rated excellence of flight performance and our measure of grip tension might conceivably be due to any one or any combination of at least the following influences:

1. Inadequacy of our measures of what the instructors meant by tension.

2. Inadequate size of population sample.

3. Unreliability of the estimates of excellence of flight performance.

4. An actual lack of covariability between a "true" measure of tension and a "true" measure of flying skill.[12]

The next step appeared to lie in a test of the first alternative named above. The experimenters had long felt that grip tension was too localized an index of tension and they had increasingly become convinced that they must attempt to search for other bodily reverberations of this condition. This conviction was given added force by the realization that, in the clinical literature of the subject, the term tension was often used in combination with the term apprehension.

Development and Standardization of Equipment. In realization of this situation, funds were requested for a phase of intensive research and development which would yield, it was hoped, more delicate indicators of excessive muscular tension and additional means of studying the involvement of other bodily systems. A special report[13] describes the myo-voltmeter which was designed and developed during the early months of this experimental phase by Carney Landis, New York Psychiatric Institute. Like all other apparatus employed in the study, it had to meet very restrictive requirements as to size and weight, so that it might come within the baggage requirements of the light airplane used in this project. Some months of

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[12] Editor's Note. Another possible explanation might be that although the relationship between tension and over-all proficiency is low for the training program as a whole, high relationship might exist within portions of the training program. Stage B, for example, exhibited the highest frequency of tension for take-offs and landings (see Table 2).

[13] Landis, C. Flight myo-voltmeter, Model 3. August 1941. Progress report in the files of the Committee on Selection and Training of Aircraft Pilots.

work finally brought about the development of an instrument which met the necessary requirements of sensitivity, compactness, and ruggedness, a combination by no means easy to secure. This instrument amplified, rectified, and integrated the electrical output of the muscles to which its electrodes were attached. When connected to an ink-writer installed in the flight analyzer, it provided a direct recording of muscle action potentials.

Preliminary tests, on the ground and in the air, indicated that the myo-voltmeter could be depended on to produce accurate records of the activity of the muscle over which the electrodes were attached. This was regarded as more dependable and more interpretable than the indirect index of muscular activity provided by the pneumatic chamber on the control stick.

A further check on muscular activity was provided by the installation of a device designed by E. L. Kelly, Purdue University, in connection with another project conducted under Committee auspices. This was a device which, when attached to the rudder pedals remained inoperative as long as pressure was applied with only one foot. When, however, the student pilot pressed simultaneously on both pedals (always an unnecessary activity) the fact was indicated on the recorder drum.

To get at other bodily reverberations, it was decided to employ a specially designed cardiotachometer to obtain, on the flight analyzer drum, a continuous record of heart rate. It was also found possible to install a pneumograph, employing a conventional rubber tube around the chest of the subject for recording variations in chest diameter on the drum of the flight analyzer.

Finally, a signal switch was provided so that the special instructor could signal, by code on the drum, the nature and the beginning and end of any maneuver. Since the special instructor was to be one of the project directors (A. C. Williams) there was reason to believe that these signals might be meaningful.

Installation of the above equipment had eliminated from the flight analyzer most of the units that it had contained during the First Experimental Phase. It was now recording: airspeed, grip tension, myo-voltmeter readings, cardiotachometer readings, pneumographic tracings, signals from Kelly's foot pedal recorder, maneuver code from the instructor. Figure 1 is a schematic representation of the procedure employed for the recording of these variables on the flight analyzer record.

All of this gear (see Figure 2) was placed in a J-4 Cub airplane. This is a side-by-side coupe, provided with a baggage capacity rating sufficient to allow for the equipment noted above. Preliminary tests showed that the subject was not unduly restricted by having on his person the electrodes for myo-voltmeter and cardiotachometer and the tube for the pneumograph.

Phase 2 was devoted almost entirely to the calibrating of the instruments described above. Many trials were run off, with A. C. Williams as

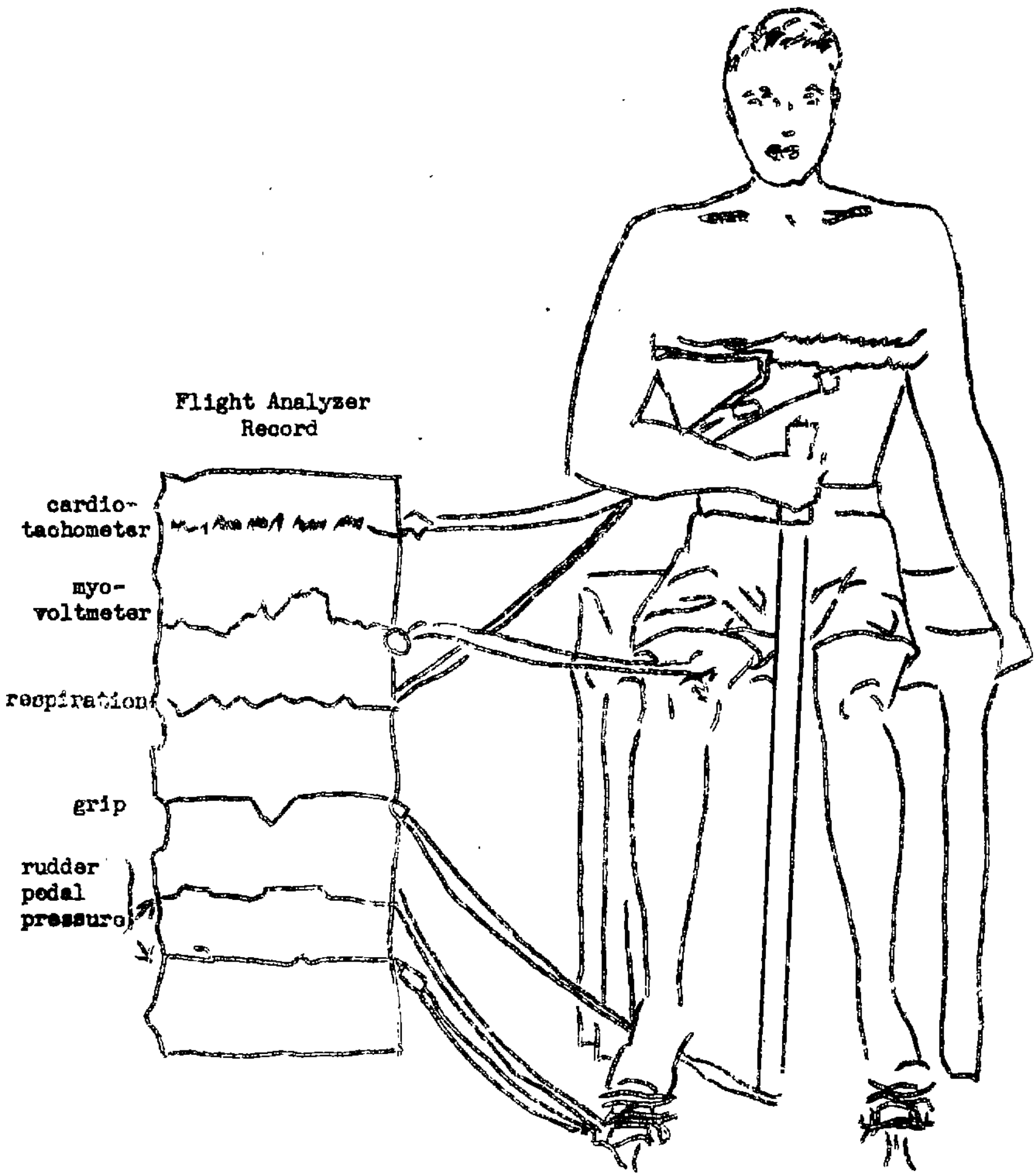

FIGURE 1

VARIABLES RECORDED DURING FLIGHT

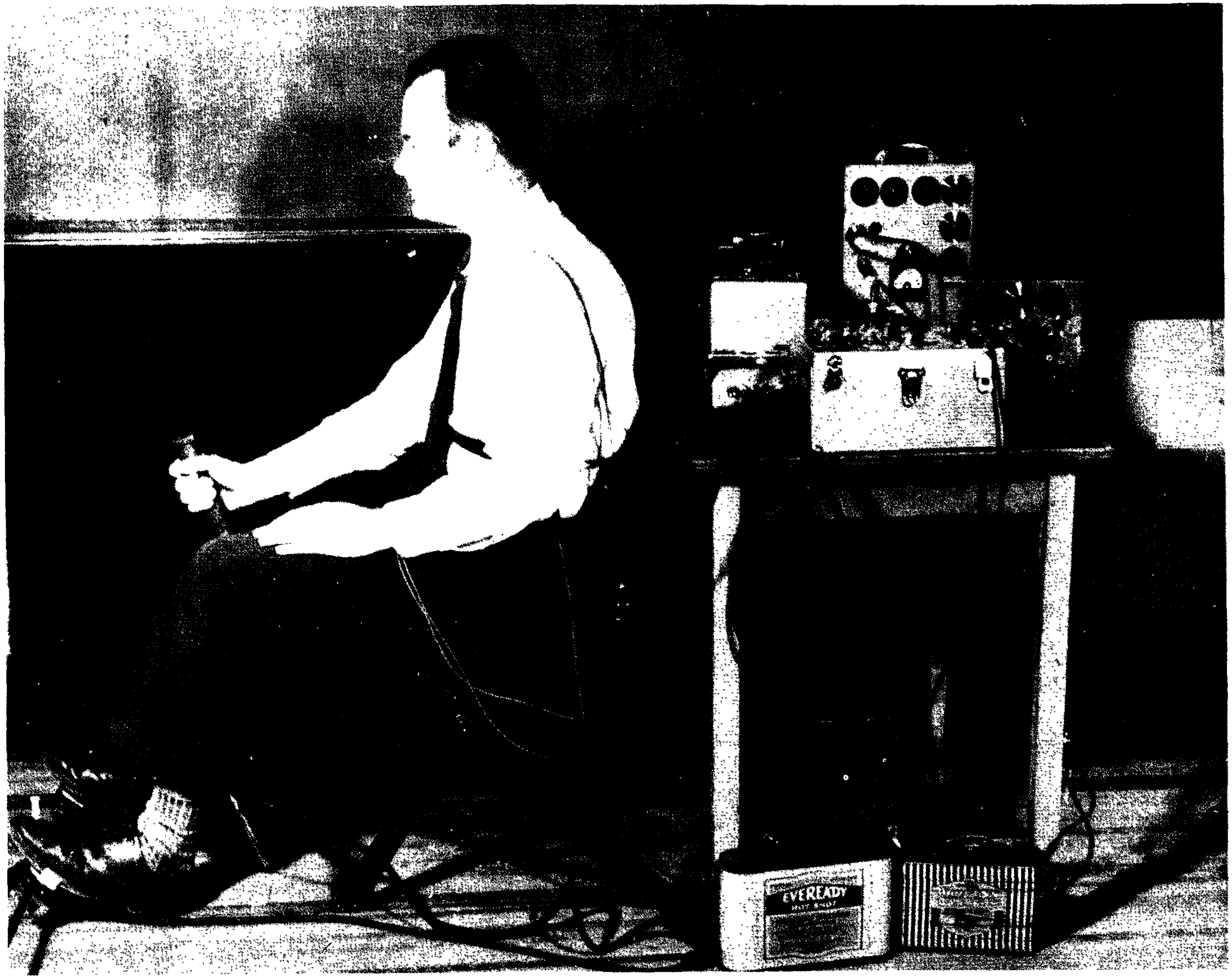

FIGURE 2

EQUIFMENT FOR RECORDING TENSION INDICES DURING FLIGHT instructor and graduate students or staff members serving as experimental animals. In the course of these runs it was possible to adjust the performance of the various instruments to what were seen as the experimental requirements of Phase 3.

It was found, for example, that the best location for the myo-voltmeter electrodes was over the large extensor muscles of the thigh. Here it was possible to obtain clear-cut records of muscle potentials with minimum interference from the other electrical rhythms of the body. It was also found that individual differences in output could be acceptably controlled by adjusting the sensitivity of the myo-voltmeter so that normal movement of the rudder pedal did not record while excessive employment of the muscle produced a definite record.

Preliminary runs showed that the myo-voltmeter records could be scored in much the same manner as that used in handling the earlier grip tension records. Heart rate and respiration rate were merely counted and recorded in rate per minute. The Kelly device yielded three categories of rudder pedal tension: none at all, a moderate amount, and a great amount. These were treated by simply tabulating the maneuvers in which each of the three occurred, regardless of duration.

THIRD EXPERIMENTAL PHASE (1942-1943)
Extensive Investigation by Means of Various Somatic Indicators of Tension

The improved recording devices developed in Phase 2 were ready for field use. Based on what had been learned in Phase 1, it had been decided to take measurements of tension during four specially designed flights only. By obtaining these measurements on 50 primary Civilian Pilot Training students, it was expected that an acceptably broad base for the final analysis would be available. Each of the four test flights had been specially designed to contain maneuvers in which tension has been notably present in Phase 1. In other words, the stage had been reached in which training was at last to be subsidiary to research rather than the reverse.

At each of the four major stages of training the flights called for four take-offs and landings, steep turns, and a simulated forced-landing -- all maneuvers which had previously brought about well developed signs of tension. Criterion data were to be obtained from detailed notes and descriptions of performance on these 200 flights made by the instructor during the flight, as well as his over-all rating of competency for the student pilot. The original experimenter was no longer available to act as instructor, but the services of an experienced CAA inspector were obtained and there was every evidence that he would carry out the design with good insight.

The extensive phase of the experiment thus got under way in very favorable circumstances. New and delicate instruments were available; the experimental design permitted of a new degree of control; and the new experimental pilot was attacking the problem with intelligence and vigor. At this point, however, the following events transpired: war was declared; members of the project staff were called to active duty; the Civilian Pilot Training program was temporarily suspended; the CAA inspector was sent to another assignment; and the experimental airplane was demolished by the collapse of the hangar during a snowstorm.

Experimental Accomplishments. These conditions produced handicaps which will be readily appreciated. Where modification was possible, however, the attempt at resolution of the above difficulties was made. A plane, similar in type to the destroyed Cub coupe, was rented; a new pilot was hired to replace the CAA inspector; and when the Civilian Pilot Training program re-opened runs were obtained on as many students as possible, although there was considerable attrition as experimental subjects began to enter the military services.

By the means noted above, at least one record apiece was obtained for each of 29 students before the last remaining research director was summoned to active duty. Each flight consisted, as noted above, of four take-offs and landings, four series of steep turns, and one simulated emergency. After each flight the instructor wrote a paragraph describing the flight, including specific comments on the apparent tenseness of the student, his flight aptitude, and the errors he made during the test flight. He also rated each student in comparison with others as to general flying ability.

Results. Because of the unfortunate occurrences noted above, the results to be presented for this phase are not complete. The gaps in the evidence and in the analysis of results will be obvious. The authors of the report, however, feel that it is better to present a report that is incomplete than to jettison materials which may be potentially significant for further research in this area. Specific data are shown where positive outcomes are to be mentioned. However, the authors have felt free to mention indifferent outcomes or unsubstantiated trends without presenting data which, because of statistical unreliability, add nothing to the findings.

1. Covariability of Indicator Scores with Instructor Ratings. The war caused incompletion of flight courses and failure to complete the experimental design. As far as the data go, however, there is no evidence of any significant covariability of any of the indicator scores as against the ratings on flight competence or the ratings on tenseness assigned by the instructors. This statement cannot in any way be regarded as final. It can properly be accepted as indicating that bodily involvements, as measured in this study, quite probably cannot be expected to vary predictably with the flight rating assigned by the instructor. Even if such ratings had not been shown by later research to be very low in reliability, the findings of Phase 4 of this research would lead one to anticipate that this result was inevitable.

2. Influences on Myo-voltmeter Scores during Landings. Sufficient data were available to permit the calculation of analysis of variance for myo-voltmeter scores during landings. The results of the analysis, indicating the sources of variation in myo-voltmeter scores, are shown in Table 6.

TABLE 6

ANALYSIS OF VARIANCE OF MYO-VOLTMETER READINGS DURING LANDINGS

Source of Variation	df	Sum of Squares	Mean Square	p value
Total	79	135.70	1.72	
Between individuals	19	111.90	5.89	<.01
Between flights	3	5.28	1.76	<.01
Interaction	57	18.52	.33	

The above data give statistically significant indication that the major source of variability in myo-voltmeter scores is that of inter-individual variation. This is encouraging for future research. It is also noteworthy that, although variability from flight to flight is not a heavy contributor to over-all variability, its contribution is significant. It should also be noted that the conditions of research employed resulted in a very small residuum of effects attributable to experimental error (interaction). In sum, the above data are taken to indicate that muscular activity, as indicated by myo-voltmeter readings from a specific muscle group, varies reliably between individuals and between flights by the same individual. The measurement thus shows promise for use in later researches on muscular levels of activity in flight training.

3. Influences on Respiration during Certain Maneuvers. It was possible also to carry out an analysis of variance for pneumographic recordings made during the four basic maneuvers. The resulting data are shown in Table 7.

TABLE 7

ANALYSIS OF VARIANCE FOR PNEUMOGRAPHIC RECORDINGS DURING STANDARD MANEUVERS

Source of Variation	df	Sum of Squares	Mean Square	p value
Total	319	7413.22	23.24	
Individuals	15	5624.47	374.96	<.01
Flights	3	16.36	5.45	>.05
Maneuvers	4	512.30	128.07	<.01
Indiv. x flts.	45	356.39	7.92	<.01
Indiv. x maneuv.	60	401.70	6.69	<.01
Flt. x maneuv.	12	68.70	5.71	<.01
Indiv. x flt. x maneuv.	180	433.50	2.41	

In the case of the pneumographic recordings, inter-individual variability again stands out as a highly significant contributor to over-all variability in score. Maneuvers are also of marked influence; and a review of the means for the several maneuvers shows that take-offs and landings are accompanied by the larger increases in the rate of respiration. In all, it is noteworthy that, because of the small contributions from other sources, one could do a reasonably accurate job of predicting pneumographic score, given only the individual's "normal" respiration rate and the name of the maneuver to be performed. Here is apparently an indicator worthy of future study.[14]

4. Other Evaluations of the Findings. Some evidence appeared to indicate that certain students may be identifiable as "stickmen" and others as "ruddermen." That is to say, some consistently showed grip tension but no rudder tension while others reversed this situation. There was no evidence of the existence of "take-off men" and "landing men," as regards tension recordings. There seemed to be, rather, a bimodal distribution, with some showing signs of excess muscular output on both take-off and landing, while another group showed little involvement on either maneuver. Also, there was a consistent and general tendency for heart rate and respiration rate to increase on take-off; and there were signs of partial adaptation in this as training progressed. Heart rate also tended to show an increase on landing.

The main outcome of this truncated phase of the experiment was its indication that the instructor appeared to be unaware of the relative amount of excess bodily involvement shown by his students during a training flight. The small residuum of the original research staff was thus faced with a situation which might be phrased thus:

> "When an instructor states that a student was tense during an instructional flight, he either does not know what he is talking about, or he is talking about some syndrome of which excess somatic involvement is not a necessary and invariable constituent."

In the face of this situation, the remaining investigators were brought to a stage of research which, for investigators less naive or better forewarned, should actually have been the starting place for the whole research program. This was simply to go directly to the instructors to see if they, on direct interrogation, could tell us what they meant when they spoke of a student as being tense. In effect, an attempt was to be made to obtain from the instructors a redefinition of the basic problem. Having failed significantly ourselves in translating a layman's statement into a technological research question, we were forced to ask the instructors to attempt to make the translation. This is reported as Phase 4 of this project.

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[14]It should be mentioned, however, that breathing pattern has been given attention by investigators. See: Nielson, J. M., and Roth, P. Clinical spirography. Archives of Internal Medicine, 1928, 43, p. 132.

FOURTH EXPERIMENTAL PHASE
The Questionnaire Approach

As stated in the section describing Phase 3, there was reason to believe that the instructor who described a student as tense was referring to something over and beyond muscular tenseness. If it were a fact that tension to the instructor was a syndrome of which muscular tenseness was not a necessary and invariable part, the experimenters hoped that direct inquiry, addressed to a group of instructors, might reveal the true state of affairs. Such an inquiry, at any rate, was plainly prerequisite to any further investigation in this area.

Informal inquiry among instructors served only to strengthen the belief that tension means many things to many men. One instructor, for example, stated spontaneously that one of the investigators had been tense in the course of a particular training flight. Asked what he meant by the statement, he replied: "Oh, his muscles weren't tense at all; he was just trying too hard." Here was one instructor, at least, who was defining tension in a way that was sharply at variance with the definition presumed in this research. Informal questioning of other instructors added to the conviction that at least four or five major categories of behavior were actually being swept up together under the term tension. It appeared also to be true that some instructors regarded tension as a cause, others as an effect. And it was noted that some were applying it to symptoms that were directly observable, while others used it only to describe some generality that had to be inferred and was not in itself observable in student behavior.

It was decided to approach the basic problem of definition through a set of general questions, each of which was to be followed up by such further inquiries as the occasion might seem to demand. The five fundamental questions which were to be asked of all respondent instructors, were as follows:

1. Have you ever instructed students who you thought were tense?

2. Specifically, what sorts of things did these students do that made you believe they were tense? How did you know they were tense?

3. What, in your experience, are the different ways in which a student can be tense?

4. Do you ever employ any method for the purpose of testing whether or not a student is tense? If so, what is the method?

5. If a student is tense, what effect does this have on his flying?

The wording of these questions was sometimes varied to meet a specific setting. The purpose of the questions, it must be understood, was not to obtain a neatly tabulated series of categorical replies; they were intended, on the other hand, to make a qualitative exploration in a field in which little was known. It was regarded as more important to avoid influencing the free response of the instructors than it was to be sure that given reply would fit accurately into any pre-existing theoretical structure of replies.

This flexible exploratory use of questions has, perhaps, reached its most effective development at the hands of Lazarsfeld and his co-workers. In essence, it consists of asking a pre-arranged question of all respondents, and then of following up by variable questions until the respondent has given a significant and unambiguous response to the basic question.

An example may help to make this clear. Under Question 2, the instructor is asked to state how he knows when a student is tense. This question was put to all respondent instructors. One instructor replied: "Well, it's easy to tell when a student is tense; he is all tightened up." The reply as it stands means little or nothing. To obtain insight into what the instructor meant by "all tightened up," it was necessary for the interviewer to go further and ask, as a follow-up, how the instructor knew that the student was "tightened up." He could drop the line of inquiry when the instructor stated that this "tightening up" took the form of hunched shoulders, feet braced against the rudder pedals, etc. Without asking leading questions, the interviewer had led the respondent from a vague and ambiguous answer in general terms to a specific, observable, and unambiguous description of behavior.

In sum, flexibility in questioning was permitted so that all respondents might be led to answer in terms of something directly observable, rather than of something inferred or, indeed, merely named. They were led to name effects, rather than presumed causes of these effects. While the effort did not always meet with success, the general outcome of this mode of inquiry was in the form of a list of specific types of behavior which could be directly observed and which could, accordingly, be subjected to investigation and verification at some later date.

Before turning to the results, it will be well to make note of certain shortcomings in this method. The outstanding weakness of this approach is that, lacking a full recording of the original response of each instructor, some material was certainly lost in reducing his replies to notes on what he said. Rice,[15] in a classic study, has shown how unconscious bias may enter to distort non-verbatim notes by fitting them into categories colored by the tacit presuppositions of the interviewer. There is little reason to doubt that both loss and distortion occurred in reproducing briefly the replies of those who were questioned.

Further violence is done to the original results when they are grouped into categories for intelligibility in analyzing the responses. Thus we have employed a category "resistance to passive movement of the controls."

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[15]Rice, S. A. Contagious bias in the interview. Amer. J. Sociol., 1929, 35, pp. 420-423.

Under this category come a variety of original responses. One instructor, for example, replies that he notices resistance when he takes over the controls. A second reports such resistance when he instructs the student to "follow through" on some maneuver performed by the instructor. A third instructor notes that certain students resist his pressure on the stick during turns, while a fourth reports that the student "rides the rudder" against the instructor's attempt to apply correction. These responses are grouped because they contain a supposedly common element in that a movement made primarily by the instructor encounters resistance undesirably applied by the student. Grouping them together allows us to handle these varied responses more effectively. Only later research will show whether we have lost valuable raw material by failing to observe significant points of difference which we have overshadowed by the fact of grouping.

Methods used by Instructors to Detect the Presence of Tension (Question 4). It may be appropriate to begin our account of this inquiry by listing the methods by which instructors seek to learn whether a student is to be described as tense at a given time. The instructors, under this question, were asked to describe any methods they used "for the purpose of testing whether or not a student is tense." It is a commentary on the generality and ambiguity of the concept of "tenseness" to report that 33 of the 63 respondent instructors stated that they had no specific test and that, indeed, the condition of tenseness was so obvious as to require no testing. Those who employed a specific test or tests supplied the information listed below which indicates what they did while the student was flying the plane: 12 of the instructors moved all controls to feel resistance, 6 tested by hand for pressure on rudder pedals, 5 noted the student's facial expression, posture, etc.; 3 tapped rudder pedals with feet to check resistance, 3 observed student's grip, 2 tested by hand for tension in rudder cables, and 1 gave the student a difficult forced landing. Further inquiry suggested that this is not a representative list, since certain instructors who said they used no test mentioned symptoms of tension which could have been determined only by one of the tests listed above. It would be encouraging to conclude that tension resided chiefly in the legs, if one were to take in all literalness the fact that at least a third of the entries have to do with the rudder pedals and cables. The apparent significance of this, however, is reduced by the reflection that these cables and pedals lie close to the instructor's hands and that the choice of this test may be enforced chiefly by availability. The data at least contain a strong suggestion that the term tension may have several different meanings, a suggestion which may be verified by turning to the other four questions which were posed to the respondent instructors.

Occurrence of Tension (Question 1). Sixty-three Civilian Pilot Training instructors were asked, in individual interviews, the question: "Have you ever instructed students who you thought were tense?" Sixty-two gave affirmative answers. The one remaining instructor gave a negative answer but remarked that he had just taken over his first group of students, receiving them after they had already had twenty hours of instruction.

Some of the respondent instructors stated that they had had one or two tense students; others stated that they expect all students to be tense in the early stages of instruction. In general, there was agreement that tension was commonplace during the first hours of instruction but that it normally tended to disappear after a few instructional periods. The replies indicated that the student who remained tense during the later stages of training constituted a real problem.

Symptoms of Tension (Question 2). The 62 instructors who had had experience with tense students were next asked the question: "How did you know they were tense?" Frequently this was put in the longer form of asking what specific sorts of things these students did that would lead an instructor to describe them as tense. Each respondent was encouraged to name as many symptoms of tension as he could. In all, there were 212 symptoms named by the 63 respondents. These overlapped frequently, as instructors tended often to name the same or similar symptoms. It appears possible to group all of these responses under 29 basic categories, which are given in order of frequency of mention in Table 8.

TABLE 8

INSTRUCTORS' STATEMENTS ON SYMPTOMS OF TENSION

		Frequency of Mention
1.	Resistance to passive movement of controls	45
2.	Jerky or abrupt control movement	34
3.	Excessive perspiration	20
4.	Tight grip on stick	18
5.	Staring at fixed point	15
6.	Tense facial expression (darting eyes, gritted teeth,etc.)	9
7.	Stiff posture (hunched shoulders, rigid arm, back,etc.)	9
8.	Inability to absorb instruction	7
9.	Poor coordination of controls	7
10.	Overcontrolling	6
11.	Leaning against bank	6
12.	Slow, delayed reactions to stimuli	4
13.	Uncertainty of actions	4
14.	Hand tremor	3
15.	Airsickness	3
16.	Poor planning	3
17.	Undercontrolling	2
18.	Fatigue	2
19.	Nervousness	2
20.	Swkward, unnatural movements	2
21.	Unwarranted error of performance	2
22.	Overconcentration on one stimulus to exlusion of others	2
23.	Hanging onto support within airplane	1
24.	Erratic performance	1
25.	Loss of muscular control	1
26.	Inability to concentrate on anything	1
27.	Holding breath	1
28.	Hard breathing	1
29.	Freezing controls	1

It should be noted that the above are free response entries. That is to say, all of the responses noted above were given spontaneously. It will be necessary to check the relative frequencies by having some later researcher use the list above as a check list. Doubtless many of the respondents would have readily accepted many of the above list, others than those they freely named, if the whole list had been presented as a stimulus to their memories. The free response form is, however, a necessary starting place for any investigation since it has been shown that the premature use of incomplete check lists serves to distort the relative frequency of the responses obtained.

Now that the basic categories of response have been shown, it is possible to attempt to gather these responses into larger groups. Such superordinate groups, if they can be obtained, may point the way to the primary definitions of tension as the term is used by the pilots interviewed in this survey. One way of categorizing the responses is shown in Table 9.

TABLE 9

POSSIBLE GROUPINGS OF MAJOR SYMPTOMS OF TENSION

A. SYMPTOMS RELATED TO POOR FLYING PERFORMANCE
- 2. Jerky or abrupt control movements
- 9. Poor coordination of controls
- 10. Overcontrolling
- 12. Slow, delayed reactions to stimuli
- 17. Undercontrolling
- 20. Awkward, unnatural movements
- 21. Unwarranted performance errors
- 24. Erratic performance

B. SYMPTOMS RELATED TO EMOTIONAL DISTURBANCE
- 3. Excessive perspiration
- 11. Leaning against bank of airplane
- 14. Hand tremor
- 15. Airsickness
- 19. Nervousness (including 6, tense facial expression)
- 23. Hanging on to support within airplane (also possibly 29, freezing controls)
- 27. Holding breath
- 28. Hard breathing

C. SYMPTOMS RELATED TO EXCESSIVE MUSCULAR OUTPUT
- 1. Resistance to passive movements of controls
- 4. Tight grip on stick
- 7. Stiff posture
- 29. Freezing controls

D. SYMPTOMS RELATED TO RESTRICTION OF FIELD OF ATTENTION
- 5. Staring at fixed point
- 22. Overconcentration on one stimulus to exclusion of others
- 26. Inability to concentrate on anything

TABLE 9 (Continued)

POSSIBLE GROUPINGS OF MAJOR SYMPTOMS OF TENSION

E. SYMPTOMS RELATED TO REDUCED CONTROL OF ACTIONS
   13. Uncertainty of actions
   16. Poor planning
   25. Loss of muscular control

F. SYMPTOMS RELATED TO INHIBITION OF LEARNING
   8. Inability to absorb instruction

The reader may well disagree with certain of the groupings listed above. The exact assignment of any given item, however, is not important at this time. What is important is the demonstration that instructors have been shown to employ the term tension to describe a considerable variety of symptoms, many of which appear to belong in categories which are not known to be directly related to any of the other categories. In other words, instead of finding that instructors mean increased muscular output when they speak of tension, we have found that they may mean emotional disturbance, or impoverished flight performance, or restricted attention, or reduced control of action, or inhibition of progress in learning. And there is real reason to suspect that the list of alternative meanings for the term tension is not yet complete.

Effects of Tension on Flight Performance (Question 5). A partial verification of the results reported above may be obtained by turning to the answers to our fifth question. This question asked: "If a student is tense, what effects does this have on his flying?" Since this question is closely (and deliberately) interlocked with Question 2, the materials obtained under it should, to a very considerable degree, be capable of being arranged under the major categories listed for the earlier question. Table 10 shows the results of attempting such an arrangement.

While the reader may again disagree with the placing of certain of the items in Table 10, it is noteworthy that all of the responses given in answer to Question 5 can be subsumed under the general definitions and categories obtained with Question 2. This result serves further to substantiate the conclusion that there are at least a half dozen different meanings of the term tension as it is used by instructors.

Mental vs. Physical Tension (Question 3). Further light on these basic meanings of the term tension became available as we sought to determine from the instructors themselves whether they were aware of using the term in quite different settings. The question originally asked was: "What, in your experience, are the different ways in which a student can be tense?" The question proved to be highly ambiguous in that form, and we were presently constrained to substitute the more specific inquiry: "Would you use the word tense to describe a student even though his muscles were actually relaxed?"

TABLE 10

STATEMENTS REGARDING MAJOR EFFECTS OF TENSION

A. EFFECTS IN TERMS OF POOR FLYING PERFORMANCE
   1. Poor coordination (20)*
   2. Mechanical flying (20)
   3. Rough flying (16)
   4. Erratic flying (5)
   5. Under or overcontrolling (4)
   6. Poor performance (1)

B. EFFECTS IN TERMS OF EMOTIONAL DISTURBANCE
   1. Ill at ease (2)
   2. Lack of enthusiasm (1)

C. EFFECTS IN TERMS OF EXCESSIVE MUSCULAR TONICITY
   1. Rough flying (16)
   2. Over and undercontrolling (4)
   3. Fatigue (4)

D. EFFECTS RELATED TO RESTRICTION OF FIELD OF ATTENTION
   1. Restriction of perceptual field (3)
   2. Spoils "feel" (15)
   3. Spoils "speed sense" (3)
   4. Destroys orientation (1)

E. EFFECTS RELATED TO REDUCED CONTROL OF ACTIONS
   1. Poor planning (7)
   2. Poor judgment (6)
   3. Slow muscular or mental reaction (10)
   4. Lack of precision (3)
   5. Large stimulus needed to elicit response (1)

F. EFFECTS RELATED TO INHIBITION OF LEARNING
   1. Slows learning (25)

*Numbers in parentheses show actual frequency of mention.

Thirty-three instructors insisted that they would use the term tension only to describe a student whose muscles were tense, but the other 29 instructors stated that tension might be either mental or physical or both. Further inquiry revealed that mental tension was used by them to describe the behavior of students under any of the five other major categories of tension listed in Table 9. In other words, there is to be found here further confirmation for the idea that instructors used the word tension to describe a great many reactions which are not necessarily accompanied by any marked increase in the tonicity of the students' musculature.

A further check served to suggest that the difference between the two groups of instructors (those who spoke only of physical tension and those who stated that tension might be physical and/or mental) was more apparent than real. It will be recalled that all instructors had listed the symptoms of tension before they answered Question 3. This made it possible to compare the frequency with which they had named the various symptoms. If there were an essential difference, we should expect to find the "physical tension" instructors giving lists of symptoms that were widely different from those listed by the "mental tension" instructors. In point of fact, however, the lists given by the two groups do not show significant differences. The p value is .52 when a contingency table (2 x 17) is constructed to compare the frequency with which the 17 most common reasons are listed by the two groups.

The fact that these two groups of instructors list the same symptoms for tension, despite a presumed difference in the definition they would assign to the term, is taken to be quite significant. Taken with our other evidence, it appears to mean that the concept of tension is part of the folklore of aviation training -- a social inheritance of each new instructor. He makes contact with the term before he makes contact with students. He approaches the student with a vague awareness that the student may be tense and that tension is hostile to progress in learning to fly. He has a ready-made term to apply to a wide variety of adverse influences he finds at work with his students. The agreement between the two groups of instructors points to the community of experience of flight instructors; and the length of the list of symptoms suggests that almost any adverse characteristic of student behavior may sooner or later be described either as tenseness or as a result of tenseness. Perhaps the wide use of the term tension is to be explained on the psychological grounds that the word tense and its derivatives is more acceptable than the words fright, scare, nervous, etc. To say to a man, "You are frightened," seems more derogatory than to say "You are tense."

For the instructor, then, tension is not a specific descriptive concept; it is an explanatory concept. As such, it is not to be tied down to any specific phenomenon but is used with facility, and acceptance, to explain such phenomena as may be observed. It may well be that the most significant practical outcome of the researches herewith reported will be to emphasize the danger that inheres in the unrestricted use of this term. That danger may be stated about as follows:

> The folklore of aviation training provides the instructor with assurance that tense students do not ordinarily become good pilots. When an instructor encounters adverse characteristics in the flight performance of a given student, he may choose to describe the student as tense. If administrators accept this statement at face value, they may be willing to eliminate the student without further inquiry, basing their action on the folklore stated above. If such administrators can, however, be made to understand that the word

tension may refer to a wide variety of observed or inferred characteristics, they may feel constrained to inquire further as to the nature of a given student's tenseness.

The essential point is, of course, that remedial instruction cannot be focused effectively against anything as vague as the observation that a particular student is tense. Such an observation does nothing more than indicate that remedial instruction is desirable; it fails completely to suggest the nature of the remedy that is required.

To be specific, if tenseness means that a given student is "trying too hard," then his instructor must seek out the source of this apparent over-compensation, with considerable care not to cause any excessive reduction in motivation. If tenseness refers to fear reactions, on the other hand, remedial instruction must be based on insight into the etiology of the specific fear in question. And if the tenseness turns out to be a matter of hypermotility, the search for predisposing causes and therapy will turn in quite a different direction.

In fine, remedial instruction can be expected to reach effective levels only if it is directed at the control of specific behavior patterns, rather than at a symptom complex which is roughly labeled as tenseness.

<u>Summary</u>. Direct inquiry has shown that the term tension means many things to many men. Only further investigation will show which of these uses of the term refer to highly intercorrelated phenomena and which to types of behavior which are loosely related or unrelated. Meanwhile, the undefined term will remain in the vocabulary of the instructor as a potential inhibitor of maximum profit from flight training.

Since it does not appear possible to undertake the semantic re-education of thousands of instructors who already over use the term, the practical implication of these findings may be simply stated. They are taken to mean that all possible steps should be taken to focus the attention of instructors upon primary behavioral maladjustments in flight training rather than upon such secondary, derived, explanatory concepts as that of tension. Steps in this direction have already been taken by eliminating the term tension altogether from certain training record forms. The success of these modified forms in the field suggests that instructors are willing to use the types of entries like those given in Table 9, if made available. Unless and until a detailed study of the intercorrelations among these many items can be carried through, it would appear that flight training has much to gain and little to lose by the adoption of forms which employ direct descriptive, rather than derived explanatory, items.

APPENDIX A

A SUBSIDIARY STUDY TO THE MARYLAND TENSION PROJECT

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INTRODUCTION

The fact that "flight analyzers" were to be employed in the Tension Project at the University of Maryland seemed to offer an opportunity for the study of the usefulness of these instruments in providing objective data as to flight competence. The two basic instruments, it may be said, had been represented by the manufacturers (to the Committee) as giving specific, recordable information from which "the attitude and performance" of an airplane might be inferred. Since they were to be used as presumptive sources of criterion data in connection with the study of tension, it seemed desirable to carry out additional treatment of the data to appraise them as indicators of how well a given maneuver was in fact performed. An allotment of funds was granted and the project was carried on as subsidiary to the Tension Project.

The most significant outcome of this subsidiary project was the collation of detailed information based on field experience, on the Friez recorders. This information, added to similarly obtained data on these and other flight recorders,[16] provided the Committee with the background necessary for developing its own, and improved, flight recorder.[17]

Beyond that, the subsidiary project made certain explorations which are reported herewith. None of them can be regarded as final. They are made a matter of record primarily in the interest of future investigators who may have occasion to conduct researches in this general area. Such investigators will, of course, enter upon their researches with the realization that

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[16]NRC Committee on Selection and Training of Aircraft Pilots, Part II. Op. cit.

Kellogg, W. N. The use of automatic recording in analyzing the process of learning to fly. September 1940. Progress report in the files of the Committee on Selection and Training of Aircraft Pilots.

McFarland, R. A., and Holway, A. H. The measurement of flight performance in relation to piloting. March 1942. Progress report in the files of the Committee on Selection and Training of Aircraft Pilots.

Viteles, M. S., and Backstrom, O., Jr. An analysis of graphic records of pilot performance obtained by means of the R-S Ride Recorder, Part I. Washington, D. C.: CAA Division of Research, Report No. 23, November 1943.

Viteles, M. S., and Backstrom, O., Jr. An analysis of graphic records of pilot performance obtained by means of the R-S Ride Recorder, Part II. A final unpublished report in the files of the Committee on Selection and Training of Aircraft Pilots.

[17]McKay, W. The development of the C.A.A.-N.R.C. Flight Recorder. Washington, D. C.: CAA Division of Research, Report No. 35, September 1944.

no mechanical (or photographic) recorder can supply more than a partial criterion of flight competence. The authors of this report have had considerable opportunity to realize that maneuver-doing (upon which alone any recording device can give information) is only one phase of piloting. The whole matter of what we may call "air wisdom" is not represented on any mechanical or photographic record. Neither are such important areas as perceptual adequacy and emotional stability to be found in the inklines traced by any recorder. Yet these characteristics, and certain others, are justifiably of considerable importance in the over-all appraisal of pilot competence.

To be specific, an adequate recorder might show that an approach pattern was smoothly and coordinately fulfilled. The recorder will not show, however, whether the pattern was carried out in compliance with Civil Air Regulations, whether undue danger to other aircraft was involved, whether the field selected for the landing was appropriate, and whether the pilot was on the verge of emotional collapse.

In sum, the best mechanical recorder is not a substitute for appraisal by an expert. Only the fallible human instructor can attempt to integrate all of the aspects of good piloting. The psychologist can, however, buttress that appraisal by supplying more objective aids to final judgment. An adequate flight analyzer is appropriately one of these aids. Such a device as the Ohio State Inventory is another. The Armed Services have developed other aids, not as substitutes for human appraisals, but simply as aids toward the improvement of these appraisals.

DESCRIPTION OF THE STUDY

1. Instruments. The two instruments available were Friez Flight Analyzer Type 644, recording airspeed, altitude, and vertical acceleration; and Friez Flight Analyzer Type 643, known as the Control Cable Recorder, recording the movement of the cables to the three control surfaces of the airplane, viz., the rudder, the ailerons, and the elevator. Records from these two instruments were obtained on three groups of Civilian Pilot Training students at the University of Maryland. Each group originally contained 10 students; 29 of these completed the course. The first group took flight training in the spring of 1940; the second, in the fall of 1940; and third, in the spring of 1941.

2. Number of Records Available for Analysis. At the time this study was proposed, records on each of the daily flights the students made throughout the training course were to be obtained. This could not be accomplished in full, however, primarily because the nature of the training syllabus and the time allowed for its completion caused the instructor to be rushed in giving the students the required flying time. This meant that all the flights were not made in the plane in which the instruments were mounted and also that the instruments could not be repaired immediately when found not to be in proper working order.

The following table gives the number of usable records by groups for each instrument

TABLE 11

RECORDS AVAILABLE FOR ANALYSIS FROM EACH INSTRUMENT

	Flight Analyzer Type 644	Control Cable Recorder
1st Group	318	91*
2nd Group	154	154
3rd Group	143	143

*The Control Cable Recorder was not delivered until May 1, 1940, and the group started flying in February, 1940.

ANALYSIS OF RECORDS

Information Available from Flight Analyzers. The records obtained on Flight Analyzer Type 644 were used primarily as an aid in identifying maneuvers during flight. Detailed information about airspeed and altitude during maneuvers was considered essential. Such information is particularly desirable where proper performance of the maneuver includes holding a constant airspeed or altitude.

The records obtained on these two variables as the instrument was originally delivered, however, could not be read accurately. Small changes in airspeed and altitude could not be detected at all. The airspeed unit, for example, was designed to record speeds of from 40 to 200 miles per hour in a two-inch scale. The airplane used in this study had a landing speed of about 35 miles per hour and seldom exceeded 75 miles per hour in training flights around the field.

On May 14, 1940, an improvement was made in the airspeed unit which made it possible to obtain finer readings. The improvement involved the addition of a Venturi tube to the static outlet of the airspeed unit. This boosted the excursion of the pen so that full scale excursion covered speeds from well below the landing speed of the airplane to approximately 120 miles per hour. The calibration of this unit after the change had been made was necessarily rough because of lack of local facilities for making more exact calibrations.

The altimeter unit in the Friez instrument was also ill adapted to our needs. It had been designed for use in aircraft having a considerable range of altitude; and it did not lend itself readily to accurate analyses of graphic records representing training flights in a Piper Cub airplane.

The third unit gave an indication of vertical acceleration. As such it was useful primarily for showing when the path taken by the airplane involved significant departures from the uniform acceleration of straight and level flight.

The Control Cable Recorder gave a direct record of the actual movements of the rudder pedals and stick. Records were taken on the two instruments simultaneously with chart speeds in both set at 1-1/2 inches per minute. Both employed ink-writing polygraphs until September, 1940, at which time the Control Cable Recorder was changed to a wax paper recorder to get away from the ink pens which often failed to write during flights. This was believed at the time to be an improvement.

The two instruments provided (1) records of three aspects of the performance of the airplane, i.e., airspeed, altitude, and vertical acceleration; and (2) records of the control movements.

RESULTS

The outstanding fact learned from the use of these instruments was that very few maneuvers (of the sort employed in primary training) could be reliably identified from the records. Steep turns could be identified, for example, but shallow turns definitely could not. Various approaches to the analysis of the records left the authors with only the following maneuvers for use as potential criterion data: take-offs, landings, and steep eights.

Two other shortcomings should be noted. It was found that the instructor could not be depended upon to signal the start and end of a maneuver. At times no signal at all would be made, apparently due to the instructor's becoming preoccupied with his primary mission. At other times the moment of entry indicated by the instructor was plainly negated by the more objective data of airspeed, altitude, or vertical acceleration.

To the lack of reliable signals from the instructor must be added the difficulty in complete and satisfactory synchronization of the two records. These two influences, in concert, made it difficult or impossible to identify sharply the beginning and end of most of the gentle maneuvers to be found in primary training.

There is no need here to comment at length on the criterion against which these objective data were to be checked. Other publications[18] of this Committee have dwelt in detail with the generally low reliability and questionable validity of instructor judgments. Such judgments are, however, still the ordinary basis for administrative action in the Armed Serv-

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[18]Johnson, H. M., and Boots, M. L. Op. cit.
Kelly, E. L., and Ewart, E. S. A preliminary study of certain predictors of success in the Civilian Pilot Training Program. Washington, D. C.: CAA Division of Research, Report No 7, December 1942.

ices and in civilian aviation. As in the tension study, we were forced here to accept the judgment of the instructor. To bring this dubious criterion to as good a level as was then possible, we had each instructor go through a paired comparison procedure for his group of ten students. The outcome of the paired comparison was then used to rank the students according to their presumptive level of flight competence.

1. Take-offs. Conferences with instructors suggested that there might be striking differences in the manner in which the elevator controls were handled during the take-off. According to the prescribed procedure, the stick was to be brought back smoothly as the plane approached adequate airspeed on the ground, brought forward slightly to level off when airborne, and then again brought smoothly back to the position maintained during the climb. The instructors suggested that, while we should find our best students doing this, we might expect to find the poorest students "pumping back and forth" on the stick as they fumbled for adequate positioning of the elevators.

Accordingly, procedures were established for counting all regressive movements of the elevator control during take-off, regressive movement being defined as any movement contrary to the general trend of control movement. For all take-offs, the regressive movements were counted within a 12-second period terminating at a point where a climbing attitude was definitely assumed, a point readily identifiable in the records. The record thus included take-off run and initial airborne handling of the controls.

While our conferences with instructors had not led us necessarily to presume any over-all relationship between regressive movements and performance in take-off, they had led to the belief that, at the very least, our best and our poorest performers would be differentiated in this regard. Inspection of the data for all 26 available students failed completely to show any consistent trend in the relationship between these two variables. Table 12 presents a comparison of the two highest rated and two lowest rated students for whom records were available in each of the three groups.

There is nothing in these data to suggest that the students named as best by the instructor will be differentiated from those named as worst in terms of number of regressive movements in handling the elevator control during take-offs.

2. Landings. Discussion of technique in landings again brought forth the opinion that the best students would show a smooth bringing back of the stick, with the poorest students handling this control in a tentative, trial-and-error fashion. Accordingly, a study was made of regressive movements of the elevator control during landings.

In this case, a regressive movement was defined as any movement contrary to the expected trend during a 30-second period terminating when the airplane first touched the ground. The appropriate computations were made for all available flights. The basic data are shown in Table 13. It will

TABLE 12

MEAN NUMBER OF REGRESSIVE MOVEMENTS ON STICK IN TAKE-OFFS AND LANDINGS FOR THE TWO BEST AND TWO POOREST STUDENTS IN EACH GROUP

Group	Student	Number of Recorded Landings	Mean Number of Regressive Movements
I	High C*	54	2.44
	High E	23	2.52
	Low H	35	1.40
	Low I	34	2.62
II	High A	31	2.45
	High B	59	2.93
	Low H	85	3.29
	Low I	15	2.73
III	High A	9	3.89
	High B	55	3.76
	Low I	65	4.12
	Low J	59	3.81

*In Group I the 1st and 2nd students are actually the 3rd and 4th in the rank order for this group. No data are available for the two rated 1st and 2nd because they finished training before the Control Cable Recorder was delivered. In Group II, records are not available for one early washout.

TABLE 13

MEAN NUMBER OF REGRESSIVE MOVEMENTS OF CONTROL IN LANDINGS FOR THE TWO BEST AND TWO POOREST STUDENTS IN EACH GROUP

		Mean Number of Regressive Movements		
Group	Student	All Flights	1st 3 Flights	Last 3 Flights
I	High A	4.8	5.1	4.8
	High B	5.4	5.2	6.0
	Low I	5.0	4.1	4.9
	Low J	3.7	4.2	4.0
II	High A	6.5	7.7	5.0
	High B	7.1	5.0	9.0
	Low H	7.0	6.7	8.0
	Low I	6.2	4.7	6.9
III	High A	8.2	8.8	-
	High B	8.3	7.6	8.8
	Low I	7.4	7.2	7.4
	Low J	7.1	5.4	9.0

be noted that the data are subdivided for a comparison of the first 3 and last 3 flights, to permit a check on the possible occurrence of differentials in learning effects.

Inspection of the data revealed no evidence of a significant trend. In the case of the best and poorest pairs of students, shown above, there is nothing to suggest that regressive movements of the elevator control in landings will constitute a good index to the over-all rating assigned by the instructor.

3. Airspeed in Take-offs and Climb. In order to check the hypothesis that poor students consistently climb at a steeper angle and at slower speeds immediately after take-offs, analysis was made of the airspeed record during this period of flight. This could only be done on the records taken after the Venturi tube was added to the airspeed unit. For the first group, such records were available only for the last few flights of seven subjects. All of the records taken on the second and third group have the improved airspeed recording. The index used for this was the number of 4-second intervals from the time the airplane leaves the ground until the airspeed reaches approximately 55 miles per hour. In Table 14 these data are presented in terms of the per cent of the total number of take-offs in which the airspeed took more than the specified number of seconds to reach 55 miles per hour. Although there are differences between the students on this variable, there is no trend which would suggest relationship between this and flying ability which holds for all three groups.

TABLE 14

THE NUMBER OF OCCASIONS THAT AIRSPEED TOOK AT LEAST THE DESIGNATED TIME TO REACH 55 MPH FOR THE TWO BEST AND TWO POOREST STUDENTS IN EACH GROUP

Group	Student	8 sec.	12 sec.	16 sec.	20 sec.	No. of Take-offs
I	High C	16	3	0	0	37
	High E	25	8	8	8	24
	Low H	39	31	23	20	40
	Low I	16	16	12	8	25
II	High A	82	47	23	11	17
	High B	81	47	31	25	32
	Low H	75	56	36	32	25
	Low I	78	68	58	53	41
III	High A	85	70	50	45	20
	High B	95	87	80	80	60
	Low I	68	42	33	29	69
	Low J	63	49	35	35	59

4. Steep 8's. Steep 8's were selected for analysis because they contained a series of turns, thus providing a comparatively easily identified pattern. In the analysis of turns in steep 8's, an attempt was made to get at coordination of controls. In all turns, according to the CAA Instructor's Manual, rudder and aileron should be coordinated. A measurement of how much either the rudder or aileron control led the other could not be obtained because the beginning or end of a control movement leading to a turn could not be determined. A more subjective approach was made, however, by tracing the rudder line and superimposing it over the aileron line at the equivalent time position. Using this procedure the record was inspected to determine the number of times there was no rudder movement accompanying an aileron movement and the number of times the rudder moved in the opposite direction.

Each entry into a turn and recovery from a turn was scored on this basis. It was either checked off as satisfactory or was scored under one of the two error categories just described. Extraneous movements which did not fit into the pattern of the series of eights were ignored. Each student's score was thus the percentage of the total number of entries and recoveries from turns in eights inspected in which there was no accompanying movement or opposite movement as defined above. Because of the subjective way of scoring the turns, the records were read at two different times two weeks apart. The scores for mean readings for each student are presented in Table 15.

The student rating poorest in this group was changed to another group before reaching the stage of training including steep 8's. The first two students, as mentioned before, finished training before the Control Cable Recorder was delivered. Therefore the rank order in this table actually runs from third through ninth. Unfortunately (for this project at least), steep 8's of the type which could be identified here (referred to as eights

TABLE 15

PERCENTAGE OF TURNS IN STEEP 8'S IN WHICH CONTROLS WERE NOT COORDINATED*

Student	Per Cent Uncoordinated Use of Controls in Steep 8's**
B	5%
C	8%
D	11%
E	11%
F	12%
G	27%
H	32%

*No records on Steep 8's available for 3 students.
**Percentage represents the average of two independent readings of record.

on pylons to distinguish from eights around pylons which involve more shallow turns) were eliminated from the training syllabus after the first group. The shallow eights do not give a clear-cut pattern which can be identified and no steep 8's are available in the records of the second and third group. The data in Table 15 are shown solely to suggest that this area warrants further study.

SUMMARY

In general, the simple relationships suggested by conferences with instructors were not supported by our results. This may be due to an actual lack of relationship between these variables and true flight competence, or it may be traceable largely to the incompetence of the instructors in appraising the over-all flight competence of their students. Later researches[19] may confirm the hypothesis that handling of the controls plays a smaller part in the evaluation of flight performance than instructors are inclined to think. The writer of this report suspects that they will. In the meantime, the Committee has set the stage for a repetition of the experiment reported herewith, a repetition made potentially significant by the availability of improved instructor ratings and an improved graphic flight recorder.

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[19] Editor's Note. Subsequent studies, involving objective recording of flight performance, have demonstrated differences (in terms of indices derived from analysis of the records) between pilots of varying degrees of proficiency. W. N. Kellogg, for example, using an experimental graphic recorder, found that the number of regressive movements during landings of beginning students was much greater than those of instructors (see: NRC Committee on Selection and Training of Aircraft Pilots. The psychology of learning in relation to flight instruction. Washington, D. C.: CAA Division of Research, Report No. 16, June 1943). Viteles and Backstrom, in a study of the Redhed Flight Analyzer, found characteristic differences of both qualitative and quantitative nature among pilots (see: Viteles, M. S., and Backstrom, C., Jr., Part I and Part II, op. cit.). The photographic method of recording has yielded similar findings. Motion photographs of recording instruments have been analyzed both in terms of qualitative and quantitative indices and have proven to be a valuable source of data for the evaluation of pilot performance, particularly with respect to the "skill elements" required for successful piloting (see: Viteles, M. S., and Thompson, A. S. The use of standard flights and motion photography in the analysis of aircraft pilot performance. Washington, D. C.: CAA Division of Research, Report No. 15, May 1943. Also, Viteles, M. S., and Thompson, A. S. An analysis of photographic records of aircraft pilot performance. Washington, D. C.: CAA Division of Research, Report No. 31, July 1944).