A STUDY OF THE EFFECT OF TRAINING IN SLOW FLIGHT ON LANDING PERFORMANCE

by

David Bakan
R. Y. Walker
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A report on research conducted at the Institute of Aviation Psychology, University of Tennessee, Knoxville, Tennessee, in cooperation with the University of Rochester, Rochester, New York, and the University of Pennsylvania, Philadelphia, Pennsylvania, under the auspices of the National Research Council Committee on Selection and Training of Aircraft Pilots, from funds provided by the Civil Aeronautics Administration and the Tennessee State Bureau of Aeronautics.

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Committee on Selection and Training of Aircraft Pilots

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NATIONAL RESEARCH COUNCIL

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Committee on Selection and Training of Aircraft Pilots

April 18, 1947

Dr. Dean R. Brimhall
Assistant to the Administrator
for Research
Civil Aeronautics Administration
Room 5217, Commerce Building
Washington 25, D. C.

Dear Dr. Brimhall:

Attached is a report entitled A Study of the Effect of Training in Slow Flight on Landing Performance, by David Bakan, R. Y. Walker, and Seymour Wapner, submitted by the Committee on Selection and Training of Aircraft Pilots with the recommendation that it be included in the series of Technical Reports of the Division of Research, Civil Aeronautics Administration.

The report is another in the series growing out of research conducted at the Institute of Aviation Psychology through the cooperation of the University of Tennessee, the State Bureau of Aeronautics, the Committee on Selection and Training of Aircraft Pilots, and the Civil Aeronautics Administration. This investigation is of particular interest in that it represents an evaluation through controlled experiment of a procedure developed by flight instructors. Although not completely definitive, results pertinent to the improvement of flight instruction were obtained, as well as findings important to the design of similar experiments.

Sincerely yours,

M. Viteles

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

MSV:rm

EDITORIAL FOREWORD

The investigation of the effect of training in slow flight on landing performance, described in this report, is one in a series of studies sponsored by the National Research Council Committee on Selection and Training of Aircraft Pilots directed toward the improvement of flight training.[1] A survey of techniques used by flight instructors indicated that a number of them were employing slow flight instruction as a device for increasing proficiency in the approach and landing.[2] The present study represents an effort to determine experimentally the value of such a training procedure, which is of particular interest because of the frequency of accidents associated with a stall during the turn.[3]

The data for this investigation were collected in the course of research at the Institute of Aviation Psychology, University of Tennessee, Knoxville, Tennessee, under the supervision of Dr. R. Y. Walker. Methods used in the analysis of photographic records are largely the outgrowth of work done by M. S. Viteles, A. S. Thompson, and E. S. Ewart at the University of Pennsylvania. The statistical analysis was conducted and the report prepared in preliminary form by David Bakan and Seymour Wapner at the Statistical Office of the Committee. The final report was largely written by the Editorial Staff of the Committee on Selection and Training of Aircraft Pilots, in particular by E. S. Ewart.

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[1]Other studies in this area are described in the following reports:

Kelly, E. Lowell, and Ewart, E. The effectiveness of "Patter" and of "Fundamentals of Basic Flight Maneuvers" as training aids. Washington, D. C.: CAA Division of Research, Report No. 6, December 1942.

Tiffin, Joseph, and Bromer, John. Analysis of eye fixations and patterns of eye movement in landing a Piper Cub J-3 Airplane. Washington, D. C.: CAA Division of Research, Report No. 10, February 1943.

National Research Council Committee on Selection and Training of Aircraft Pilots. The psychology of learning in relation to flight. Washington, D. C.: CAA Division of Research, Report No. 16, June 1943.

Viteles, M. S., et al. A course in training methods for pilot instructors. Washington, D. C.: CAA Division of Research, Report No. 20, September 1943.

Kelly, E. Lowell. The flight instructor's vocabulary. Washington, D. C.: CAA Division of Research, Report No. 22, October 1943.

Ewart, Edwin S., Thompson, Albert S., and Viteles, Morris S. Evaluation of instructional techniques described as effective by flight instructors. Washington, D. C.: CAA Division of Research, Report No. 63, June 1946.

Walker, R. Y., Wapner, S., Bakan, D., Ewart, E. S. The effectiveness of directed attention to instruments as a training aid. Washington, D. C.: CAA Division of Research, Report No. 69, October 1946.

[2]Ewart, Edwin S., Thompson, Albert S., and Viteles, Morris S. Op. cit.

[3]The high incidence of accidents of this type has been indicated in research conducted by Dean R. Brimhall and Raymond Franzen. Discussion of these investigations can be found in the minutes of the Annual Meetings of the Committee on Selection and Training of Aircraft Pilots for 1944 and 1945, and in progress reports in the files of the Committee.

CONTENTS

SUMMARY

The investigation described in this report was concerned with the experimental evaluation of an instructional technique which had been developed for teaching the maneuver "landing." The subjects employed in this experiment were student pilots in the fourth and fifth flight classes at the Institute of Aviation Psychology, University of Tennessee. There were 28 subjects in the fourth flight class and 30 subjects in the fifth flight class, each class being divided into control and experimental groups.

The control groups received the conventional instruction in the maneuver "landing." That is, all landings executed in regular landing practice were of the normal power-off type. The experimental group received special training in this maneuver which comprised:

1. Emphasis on demonstration and execution of stalls from extended periods of slow flight prior to the introduction of landings, and during subsequent stall practice (through the first 17 hours of training) during which time the slow flight stall practice was alternated with practice in conventional stall procedures during dual flights.

2. Use of the power approach for initial demonstration and early practice in landings, and employment, following every third power approach, of a procedure whereby the student handled all of the controls except the throttle, being instructed to hold the plane at a constant height off the runway while the instructor varied the throttle setting This provided an extended and exaggerated period during which the subject practiced "holding the plane off."

This special training (of the experimental group) in landing was continued for the first two hours of landing instruction. Subsequently, and until the student soloed, all landing practice consisted of normal power-off landings. Following solo, power-approach and power-off landings were alternated during dual landing practice, until the seventeenth hour of training, following which both control and experimental groups received conventional training.

Criterion data on the proficiency of the subjects were obtained during check flights, administered by a flight examiner, at the seventh, fifteenth, twenty-fifth and thirty-fifth hour of training, and during "pre-check flights," conducted by the subject's instructor during the instruction period just preceding the check flight. These measures included the grades on the maneuver "landing" assigned by the flight examiner, and by the instructors during check flights and pre-check flights, respectively; as well as other general and specific maneuvers obtained through use of the Ohio State Flight Inventory and photographic records taken during flight of a concealed instrument panel. Also available were data on the vertical acceleration produced during each landing, and the number of bounces associated with the landing.

The data were evaluated by analysis of variance, where this procedure was applicable, and by chi squared where the data were dichotomous. In general, significant differences were not evident between the performances of experimental and control groups in terms of the available criteria, and unequivocal evaluation demands merely the statement that no systematic differences are indicated. However, the experimental evidence does not indicate that the slow flight training procedure in landing is less effective than conventional instruction, and therefore certain empirical evidence favoring the technique should not necessarily be considered unfounded and dismissed.

A STUDY OF THE EFFECT OF TRAINING IN SLOW FLIGHT ON LANDING PERFORMANCE

INTRODUCTION

Two important factors affecting landing performance are recognition by the pilot of cues indicating that the plane is about to stall, and his judgment of the distance above the ground at which the plane is to be leveled off. In the execution of a normal power-off three-point landing, the pilot levels the plane off at the proper height, then "slows it up," or increases the angle of attack, so that it stalls in close proximity to the ground in the "three-point" position. If the airplane is leveled off too high, a "pancake" landing will result, i.e., the plane will contact the ground with a severe jolt. If leveled off too low, the plane will "fly into the ground," contacting wheels first, and bouncing. Through proper sensing of the cues which indicate that the plane is (or is not) on the verge of stall, the pilot controls the angle of attack in such a manner that the stall occurs when the plane is just off the ground, in order that a smooth three-point landing will be made.

In the usual power-off landing the period of leveling off and landing is relatively short, i.e., a matter of a few seconds. Therefore, in normal landing instruction the period of time during which the student pilot is exposed to, and must learn to recognize, the sensory cues important to the proper execution of this critical part of the maneuver is brief.

It seemed reasonable that an instructional procedure which increased the length of the pre-stall period would allow greater opportunity for the student pilot to learn to recognize the sensory cues which indicate that the plane is about to stall. Furthermore, extension of this period prior to an actual landing would, it was felt, provide greater opportunities for the development of judgment as to the correct altitude at which the plane should be leveled off.

For this reason it was suggested that the efficiency of landing instruction might be increased: (1) if student pilots were given preliminary training in stalls from slow flight at a safe altitude before the introduction of landings, and (2) if landing instruction were introduced through employment of power approach landings during which the plane was flown the length of the runway, just a few feet off the ground, the student handling all of the controls except the throttle, and being instructed to hold the plane at a constant height off the runway while the instructor varied the throttle setting. This would provide an extended and exaggerated period during which the subject practiced "holding the plane off." It is of interest to note that this procedure for landing instruction had reportedly been used to advantage by a number of flight instructors.[1] The present investigation represented an experimental test of its efficacy.

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[1] Ewart, Edwin [illegible], Thompson, Robert [illegible], Viteles, Morris S., with the cooperation of Dean R. Brimhall. Evaluation of instructional techniques described as effective by flight instructors. Washington, D. C.: CAA Division of Research, [illegible]

PROCEDURE

Subjects and Flight Instructors. Fifty-eight subjects were employed in this investigation, 28 in the 4th flight class (Spring, 1945), and 30 in the 5th flight class (Summer, 1945). In the 4th class nine of the subjects were female and in the 5th class eight. The subjects were matched, roughly, on the basis of age, sex, and scores on a series of selection tests, and were divided into control and experimental groups.[2]

Instruction. Five flight instructors participated in the experiment, the same instructors being employed during the two successive flight classes. Each instructor taught both experimental and control subjects in each class. The assignment of subjects according to Methods, Instructors, and Classes is given in Table 1.

Training Procedures. Experimental Group. Special procedures involving emphasis on slow flight were employed in the introduction of landings, during part of the dual instruction in the execution of this maneuver, and in the demonstration and execution of stalls during the first part of the course, particularly in regard to their integration with training in landing.[3] A complete statement of the experimental instruction employed in the investigation is given in Appendix 1. Briefly, the procedure was as follows: The usual introduction in stalls prior to the introduction of landings was stressed, particular emphasis being given to execution of stalls following extended periods of slow flight. In these stalls the throttle was retarded extremely slowly, altitude being maintained by increasing the angle of attack through exertion of back pressure on the stick until the stall occurred. Practice in this type of stall was alternated with normal stall practice before introduction of landing, and during all dual stall practice throughout the first 17 hours of training. After this point the usual stall procedure was employed.

The first two hours of landing practice (for the experimental group) consisted entirely of power approach landings. On every third power approach landing the instructor handled the throttle, and directed the student to hold the plane about three feet above the runway, but to "hold it off" rather than actually landing. The instructor then varied the throttle setting, requiring the student pilot to "hold the plane off" by appropriate application of back pressure on the control stick. This provided a simulated "level-off" period of considerable duration. The instructions to the subject were "On this landing attempt I do not want you actually to land the plane. I will handle the throttle, varying the amount of power,

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[2]The tests employed were as follows:

a. Otis Test of Mental Ability
b. Mechanical Comprehension Test
c. Two-hand Coordination Test, Total Score
d. Mashburn, Total Score

[3]These procedures were employed only under the direction of a flight instructor and never in solo flight.

TABLE 1

NUMBER OF SUBJECTS ASSIGNED ACCORDING TO METHODS, INSTRUCTORS, AND CLASSES

Instructor	4th Class		5th Class	
	Control	Experimental	Control	Experimental
1	3	2	3*	3*
2	3*	3*	3*	3*
3	3*	2*	3*	3*
4	3**	3*	3*	3
5	3*	3*	3	3*

Number of cases = 58

*Denotes that one subject is female
**Denotes that two subjects are female.

and you want to fly the plane straight down the runway, making corrections for any drift and holding the plane about three feet off the ground. Remember, you are not to let the wheels touch the runway."

As noted previously, this training was continued for two hours following the introduction of landings. Subsequently, and until the student soloed, all landing practice consisted of normal power-off landings. Following solo, however, power-approach and power-off landings were alternated during all dual instruction periods through the seventeenth hour of training. After this point the training of experimental and control subjects was identical. At the initiation of each landing approach all instruments, with the exception of the tachometer, and oil temperature and pressure gauges, were blocked from the student's view to prevent the student from using the instruments rather than other cues as aids in landing. This condition applied, of course, only to the experimental group.

Training Procedure. Control Group. The students in the control group received training in accordance with the usual flight curriculum specified for approved flight training schools. This did not, of course, include the introduction of landings through use of the power approach, and did not include the emphasis on stalls following extended periods of extremely slow flight. That is, all landings practiced by the control group were normal landings, and there was no artificial extension of the level-off period.

Time Spent on Landings and Stalls by Experimental and Control Groups. It should be noted that the number of hours spent on instruction in stalls and landings was the same for both experimental and control groups. According to the CAA approved school curriculum in effect at the time, among the maneuvers covered during Stage A of the training course (through 8 hours of training or until solo) a minimum of 30 minutes was to be spent on instruction in stalls, and minimums of 1 hour were to be spent in instruction on the following maneuvers: take-off, landing, and 90° and 180° approaches. During Stage B (covering the 10 hours after solo, i.e., normally to the 18th hour of training) 2 hours were to be spent on dual instruction in precision landings, 2 hours on solo practice in precision landings, and 1 hour respectively, on dual and solo execution of stalls.

During Stage A, however, much more than the minimum time actually was spent on instruction in landing in as much as landings were, of course, made at the end of every flight, and since additional concentrated instruction in this maneuver above the minimum, normally was necessary. The instructors estimated that during Stage A, approximately 45 minutes were spent on demonstration and instruction of stalls and about 4 hours on instruction in take-off and landing, all in dual flight. This applied to both control and experimental subjects. During Stage B, both experimental and control subjects spent 2 hours of dual instruction on landing (and 2 hours of solo practice in this maneuver); and 1 hour on dual instruction in stalls (and 1 hour in solo practice on this maneuver).

The differences in training between the two groups were, to recapitulate, as follows:

1. During the 45 minutes devoted to stalls in Stage A, training in stalls from slow flight was alternated, for the experimental group, with conventional stall instruction. The control group received conventional stall instruction throughout.

2. The first two of the approximately four hours actually given to landing instruction during Stage A were devoted, for the experimental group, to the experimental training procedures. During the remaining time the conventional instruction procedures were employed. The conventional procedures were employed throughout for the control group.

3. During Stage B, the control group received two hours dual instruction in landing and two hours solo instruction, in all of which conventional instruction procedures were employed. For the experimental group, however, during the two hours of dual instruction one-half of the landings were made employing the experimental instruction procedures, and in the other half the conventional instruction procedures were employed.

4. During Stage B one hour was spent in dual instruction in stalls, and another hour in solo practice of this maneuver. For the experimental group, during the hour of dual instruction stalls from extended periods of slow flight were alternated with the conventional execution of this maneuver.

There is no record available of the actual number of landings and stalls executed by members of the control and experimental groups.

Check Flights and Pre-check Flights. Measures of flight proficiency were obtained through the administration, by a flight examiner, of check flights at the seventh, fifteenth, twenty-fifth, and thirty-fifth hour of flight training, respectively. A single flight examiner administered all of the check flights in this investigation. During the hour preceding each check flight period, the flight instructor administered a "pre-check flight" to each subject. During this pre-check flight the same maneuvers were executed as were to be included in the check flight, conducted during the next training period by the flight examiner. The order in which the maneuvers were executed during the pre-check flight was not the same, however, as during the check flight proper. The maneuvers included in each of the four check flights are presented in Appendix 3. It should be noted, however, that the principal interest of the present investigation is in the maneuver "landing," and that three landings were executed during each check flight.

Criterion Measures. In the evaluation of the flight proficiency of experimental and control subjects two types of criterion measures were obtained, i.e., general measures and specific measures. The general criterion measures represented evaluations of the over-all adequacy of the student pilot's performance on the maneuver "landing." Specific measures refer to observations made in terms of given objective and denotable aspects of performance. Both specific and general criterion measures were obtained from flight examiners and flight instructors, although some criterion measures were obtained from the flight examiner only.

The general criterion measures were represented by:

1. Over-all grades on the maneuver "landing," assigned on a percentage basis by the flight examiner during the check flights, and by the flight instructor during the pre-check flights.

2. An indication of the "satisfactory" or "unsatisfactory" nature of each landing executed during the check flights, as recorded on the Ohio State Flight Inventory[4] by the flight examiner.

3. An over-all score computed through summation of weights assigned to individual items on the Ohio State Flight Inventory marked by the flight examiner.

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[4]The Ohio State Flight Inventory (the "OSFI") consists of a series of check sheets, each page of the inventory, i.e., each check sheet, being devoted to a single maneuver. On each maneuver sheet the critical elements of the maneuver in question are indicated, and spaces are provided in which the check pilot who administered the flight test records the subject's performance, in terms of each element by checking the proper descriptive term, or entering a figure. For a full description of the OSFI and its development, see: Edgerton, H. A., and Walker, R. Y. History and development of the Ohio State Flight Inventory, Part I. Early versions and basic research. Washington, D. C.: CAA Division of Research, Report No. [illegible], July 1945. Also: NRC Committee on Selection and Training of Aircraft Pilots. History and development of the Ohio State Flight Inventory, Part II. Recent versions and current applications. Washington, D. C.: CAA Division of Research, Report No 51, November 1945.

4. An over-all score computed through summation of weights assigned to individual items on the photographic record "record sheets."[5]

The specific criterion measures, obtained from the flight examiner and the five flight instructors, were

1. The number of gs (units of vertical acceleration) produced by each landing in the check flight (or pre-check flight) as read from a vertical accelerometer.

2. The number of bounces during the landing, recorded on special forms both by instructors and flight examiner.

Additional specific measures were obtained in terms of elements on the OSFI, administered by the flight examiner during each check flight, and also in terms of data on specific elements of flight performance obtained through observation of photographic records taken of flight instruments during execution of the maneuver during the check flights. The general and specific criterion measures are presented in detail in Table 2.

STATISTICAL PROCEDURES

Two statistical procedures were employed in the analysis of data from this investigation, namely, analysis of variance and chi squared. Analysis of variance was employed in the evaluation of (1) landing maneuver grades (given by the flight examiner and by the flight instructors), (2) number of gs produced by the landing, (3) number of bounces during landing, (4) over-all OSFI score on landing, and (5) over-all photographic record score on landing. The remaining criterion measures, i.e., those of an essentially dichotomous nature, were analyzed through the use of chi squared.

Analysis of Variance. For those criterion measures to which analysis of variance was applied, a single score for each criterion measure for each flight test was computed for each student. Thus, although each student performed three landings on each flight test, the sum of scores for the three landings was used as a basis for analysis rather than the scores on individ-

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[5] Through use of a specially constructed "criterion plane," motion photographs were taken of the instruments in a concealed instrument panel. Through reading and analysis of these photographic records, objective data on specific aspects of the execution of the maneuver could be obtained. The instruments included in the concealed panel were as follows: airspeed indicator, altimeter, artificial horizon, ball-bank instrument and rate of turn, tachometer, angle-of-attack meter, and a "control indicator" by means of which the positions of the elevators, ailerons, rudder and throttle could be observed. For a more complete description and discussion of the photographic installation, see: 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.

TABLE 2

CRITERION MEASURES ON WHICH THE EXPERIMENTAL AND CONTROL GROUPS WERE COMPARED

I. General criterion measures:

A. Landing maneuver grades assigned by instructors.

B. Landing maneuver grades assigned by the flight examiner.

C. Satisfactory or unsatisfactory landing as recorded by the examiner on the OSFI.

D. Total OSFI score on maneuver "landing."

E. Total photographic record score on maneuver "landing."

II. Specific criterion measures:

A. Recorded by observer:

1. Recorded by both instructors and examiner on the pre-check flights and check flights, respectively:

a. "gs" read from the vertical accelerometer.

b. "Bs" (number of bounces).

2. Recorded only by the examiner:

a. Direction during approach constant or varied.

b. Wing level during approach constant or varied.

c. Direction during roll constant or varied.

d. Wing level during roll constant or varied.

e. Did or did not stall.

f. Stalled smoothly or abruptly in those cases in which stall took place.

g. Speed constant or varied.

h. Did or did not correct for drift when it occurred.

i. Did or did not level off at the appropriate height.

TABLE 2 (Continued)

j. Height above ground at stall was correct or incorrect.

k. Correct or incorrect clearance turns.

l. Observer did not or did assist in the landing.

m. Did or did not land in spot.

n. Did or did not make a good landing in terms of the sequence of points contacting the ground.

B. Recorded by camera:

1. Wings level or not level (artificial horizon):

   a. 5-10 seconds before contact.

   b. 0-5 seconds before contact.

   c. At the moment of landing.

2. Did or did not turn (turn indicator):

   a. 5-10 seconds before contact.

   b. 0-5 seconds before contact.

   c. At the moment of landing.

   d. 0-10 seconds after contact.

3. Stick full back (control indicator):

   a. At the moment of landing.

   b. 0-10 seconds after contact.

4. Change in angle of attack smooth or irregular:

   a. 5-10 seconds before contact.

   b. 0-5 seconds before contact.

5. Ball bank satisfactory or unsatisfactory at moment of landing.

ual landings. It is believed that these totals are more reliable indices of performance than each landing score taken separately. It is evident that these total scores are directly proportional to the mean of all three scores for a student on a given flight test.

Since there was duplication of students from flight test to flight test, the requirement of "independent random samples," necessary for the simultaneous analysis of data from more than one check flight could not be met. Therefore, separate analyses were run for each flight test.

The data were analyzed statistically by controlling the following three variables as main effects: Methods, Instructors, and Classes. The statistical control of these variables was made possible by the design of the experiment which permitted each cell of a schematic three-way table to be filled.[6] In each analysis, the variances due to the following sources of variation were calculated: Methods, Instructors, Classes, interaction of Methods and Instructors, interaction of Methods and Classes, interaction of Instructors and Classes, interaction of Methods and Classes and Instructors, and Within Groups. The ratio of the variances, F, was computed by regarding the Within Groups variance as the error term.

Chi Squared The criterion measures which were analyzed by chi squared were treated as dichotomous in nature, i.e., performance in terms of each criteria could be categorized only as "satisfactory" or "unsatisfactory." For some criterion items it was necessary to set arbitrary standards of "satisfactory" and "unsatisfactory" (or "correct" and "incorrect"). For example, in regard to the measure taken from the photographic records "wings held level (or not level) 5-10 seconds before contact," the performance on the item was considered "satisfactory" if the deviation from the level position, as indicated by the artificial horizon, was five degrees or less, and "unsatisfactory" if the deviation was greater than five degrees. The standards used for the various items of this nature are given in Appendix 2.

For other measures it was not necessary to set arbitrary standards in this manner, since the check pilot merely indicated whether the performance in terms of the item was "satisfactory" or "unsatisfactory," or "correct" or "incorrect." For example, the flight examiner noted on the Ohio State Flight Inventory whether or not the plane was leveled off for landing at the proper height.

For each landing in each flight test the data were classified in terms of four categories which can be shown schematically by the cells of a two-by-two table such as that in Figure I. The contingency of the two axes was measured by the calculation of chi squared. Since the cell frequencies were generally small, Yates' correction was used in the computation.[7]

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[6]See Table 1.

[7]Fisher, R. A. Statistical methods for research workers. (5th ed.) Edinburgh: Oliver & Boyd 1934, 96-99.

	Satisfactory	Unsatisfactory
Experimental		
Control		

FIGURE I

CONTINGENCY TABLE FOR COMPUTATION OF CHI SQUARED

It can be seen that, aside from the fact that the cell frequencies are small, the bias of which has been overcome by Yates' correction, the chis squared computed in the fashion described above are not biased.

RESULTS: I. GENERAL CRITERIA

Five of the criterion measures collected in the course of this investigation may, as noted previously, be considered general measures of landing proficiency. These are the landing maneuver grades assigned, respectively, by flight examiners and instructors, the judgment recorded by the flight examiner on the OSFI as to whether the landing was "satisfactory" or "unsatisfactory," the "over-all score" on landing derived from the Ohio State Flight Inventory, and the "over-all score" on landing derived from the photographic records. The significance of differences between control and experimental groups in terms of all of these measures except "landing 'satisfactory' or 'unsatisfactory'" was evaluated through application of analysis of variance. Differences in terms of this measure were evaluated through use of chi squared.

<u>Landing Maneuver Grades</u>. As has been indicated above, each student performed three landings on each flight test. The total of the landing maneuver grades for the three landings was taken as the measure on each student and used in the analyses. Separate analyses were run for each check flight.

The results of these analyses are summarized in Table 3. In this table are presented the means of the control and experimental groups for each check flight, and the p-values for each evaluation of the F statistic. If for any variance, except that due to Methods, the p-value was greater than .05, it is so indicated by "n.s." (not significant) in the table. The p-values for the Methods variances are given within closer limits if .30 or below.

Examination of this table shows that for the Methods variance none of the F's are significant at the orthodox 5 per cent level of confidence, and that in only one instance, on the third pre-check flight, is the vari-

TABLE 3

RESULTS OF ANALYSES OF VARIANCE FOR TOTAL MANEUVER GRADES OVER THREE LANDINGS SHOWING THE p-VALUES FOR EACH F CALCULATED; AND OBTAINED MEANS FOR THE METHODS GROUPS

Source of Variation	Pre-check Flight (Instructors)				Check Flight (Examiner)			
	1	2	3	4	1	2	3	4
Methods (M)	$>.30$	$>.30$	.10-.05	$>.30$	$>.30$	$>.30$	$>.30$	.30-.20
Instructors (I)	n.s.	.05-.01	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Classes (C)	$<.01$	n.s.	.05-.01	n.s.	n.s.	n.s.	n.s.	n.s.
M x I	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	.05-.01	n.s.
M x C	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
I x C	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
M x I x C	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Means of Grades Summated over Three Landings for Methods Groups								
Control	126.7*	163.2*	186.0	190.3	104.1*	177.3*	180.4	181.6
Experimental	126.1	155.5	201.1*	205.7*	100.9	171.7	183.4*	193.1*

*Group having better obtained mean performance.

ance significant at the 10 per cent level of confidence.

An interesting feature of the table is the patterning, i.e., the sequence of the obtained differences in means between the experimental and control groups. In both the pre-check flights and the check flights the control group shows better performance on the first and second flight tests, and the experimental group shows better performance on the third and fourth flight tests. Assuming that this patterning is not a chance event, it would indicate that the effect of slow flight training does not become manifest until later training, and that its effect is then positive.

A significant Instructors variance occurs in the second pre-check flight. Since this variance is computed on the basis of grades assigned by the instructors, its magnitude could have resulted from differences in grading practices among the instructors as well as from differences in the performance levels of the students of the different instructors.

Significant Classes variances occur in the first and third pre-check flights. These again could either be due to changes in grading practices on the part of the instructors from class to class or to differences in the levels of performance of the students of the two classes. It is possible that weather differences might have played a role in producing these significant Classes variances.

The only interaction variance that is significant in this table is that for Methods x Instructors for the third check flight administered by the flight examiner. This suggests the possibility that the effectiveness of the slow flight method of training may be a function of the instructor who administers the training. However, since the significance of the several variances and interactions followed no consistent pattern it is difficult to draw any systematic interpretations.

OSFI and Photographic Record Over-all Scores. It was considered desirable, in addition to the analysis of individual items on the Ohio State Flight Inventory (which will be discussed subsequently), to determine if significant differences between control and experimental groups existed in terms of total scores derived for the maneuver "landing" from both the Ohio State Flight Inventory and from the photographic record data sheets. In deriving this total score, weights were assigned to each item (on the OSFI and the photographic record data sheets), an item being weighted 1 if it denoted "satisfactory" performance, and zero if it denoted "unsatisfactory" performance. Satisfactory and unsatisfactory performance were defined as previously indicated. In the scoring of the records, a weight of 1/2 was assigned if an item was not marked.

The data were evaluated through application of analysis of variance, the results of these analyses being summarized in Table 4. It will be noted that the analyses are not uniformly complete. In a number of instances the data available were so grossly disproportional that they did not permit any analysis. In such cases only the means of the two groups are reported. Moreover, since large quantities of photographic record data for the fifth

TABLE 4

RESULTS OF ANALYSES OF VARIANCE FOR OSFI AND PHOTOGRAPHIC RECORD SCORES ON LANDING, SHOWING THE p-VALUES FOR EACH F CALCULATED; AND THE OBTAINED MEANS FOR THE METHODS GROUPS

Source of Variation	OSFI Total Score				Photographic Record Total Score			
	1	2	3	4	1	2	3	4
Methods (M)	n.s.	n.s.	x**	n.s.	x	n.s.	n.s.	n.s.
Instructors (I)	n.s.	n.s.	x	.01	x	n.s.	n.s.	n.s.
Classes (C)	.01-.05	n.s.	x	n.s.	x	x	n.s.	x
M x I	n.s.	n.s.	x	n.s.	x	n.s.	n.s.	n.s.
M x C	n.s.	n.s.	x	n.s.	x	x	n.s.	x
I x C	n.s.	n.s.	x	n.s.	x	x	n.s.	x
M x I x C	n.s.	n.s.	x	n.s.	x	x	n.s.	x
Means of Scores								
Control	3.64	5.52*	5.63*	6.32	7.58*	7.68*	8.33*	8.32*
Experimental	3.83*	5.48	5.51	6.80*	7.25	6.95	8.31	8.04

*Group having better obtained mean performance.
**Analysis not made.

flight class were missing, it was necessary to restrict the analysis to the fourth flight class, except with respect to Check Flight 3, for which data for both classes were available.

It is evident from inspection of Table 4 that none of the variances attributable to methods were found significant. In fact, none of the variances in the analyses of photographic data were found significant, and only two variances in the OSFI analyses reached the statistical level of confidence, viz: for Classes in the first check flight, and for Instructors in the fourth check flight. Meaningful interpretations cannot be drawn from these isolated cases. Furthermore, in regard to the Methods variable, which is of principal interest, in those instances where analysis of variance could not be employed the differences between means are extremely small, and probably would not have been found statistically significant under any circumstance.

It can be said, therefore, that significant differences between control and experimental groups were not evident in terms of the over-all scores derived from the Ohio State Flight Inventory, and the photographic record data sheets. It is of some further interest to note that with the exception of OSFI scores for Check Flights 1 and 4 the mean score for the experimental group was slightly, although not significantly, lower than the mean score for the control group. The "patterning" suggested in the case of over-all grades is not evident in so far as these "score" variables are concerned.

<u>Landing "Satisfactory" or "Unsatisfactory" (OSFI)</u>. The flight examiner indicated on the Ohio State Flight Inventory his judgment as to whether each landing was "satisfactory" or "unsatisfactory." The data for each landing on each check flight, obtained from experimental and control subjects, respectively, were evaluated by chi squared, on the basis of four-fold contingency tables as indicated in Figure I. The results of these analyses are presented in Table 5. Since for one degree of freedom the value for chi squared at the 5 per cent level of confidence is 3.841, it is evident that none of the values attained even approach this level. On the basis of this analysis it can be concluded that there is no demonstrable difference between experimental and controlled groups in terms of the flight examiner's judgment as to the "satisfactory" or "unsatisfactory" nature of the landings.[8]

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[8] In addition to the chis squared presented in Table 5, the total chis squared (obtained by summating the individual chis squared), the pooled chis squared (obtained by entering in a four-fold table the summated entries over all landings), and the interaction chis squared, which represent the difference between the total and the pooled chis squared, also were computed. (This latter statistic, which may be regarded as an index of change in contingency from landing to landing, is discussed in: Snedecor, George W. <u>Statistical methods</u>. (4th Ed.) Ames, Iowa: Iowa State College Press, 1946, 189-192.)

All of these statistics are biased, however, since each case cannot reasonably be considered to have been drawn independently and at random

TABLE 5

THE NUMBER OF STUDENTS IN EACH GROUP WHO MADE SATISFACTORY OR UNSATISFACTORY LANDINGS ON THE CHECK FLIGHTS AS INDICATED BY THE FLIGHT EXAMINER IN THE OHIO STATE FLIGHT INVENTORY

Check Flight	Landing	Experimental		Control		Chi-squared	Degree of Freedom
		Satisfactory	Unsatisfactory	Satisfactory	Unsatisfactory		
1	1	1	28	4	26	.802	1
	2	6	24	6	24	.000	1
	3	5	23	3	27	.236	1
2	1	13	15	14	16	.000	1
	2	16	12	16	14	.000	1
	3	12	17	17	13	.835	1
3	1	15	12	11	14	.308	1
	2	13	12	12	15	.071	1
	3	12	13	13	15	.000	1
4	1	12	15	14	14	.020	1
	2	18	9	14	14	.959	1
	3	15	11	15	12	.000	1

RESULTS: II. SPECIFIC CRITERIA RECORDED BY BOTH FLIGHT INSTRUCTORS AND THE FLIGHT EXAMINER

Two of the specific criterion measures most important for the evaluation of the performance of control and experimental groups are the "gs" (units of vertical acceleration produced during the landing) and "Bs" (number of bounces during the landing). It was felt that in general the plane would contact the ground with more force in bad landings than in good landings, and that similarly, a bad landing would be accompanied by more bounces than a good landing. In regard to vertical acceleration, experience indicated that a three-point landing could be made with as low as 1.6 units of vertical acceleration.

Measures of "gs" and "Bs" associated with landing were obtained both during pre-check and check flights by the instructors and by the flight examiner, respectively. As in the case of landing maneuver grades, these scores were summed for each subject over the three landings in each check flight (or pre-check flight), and differences between control and experimental groups evaluated through use of analysis of variance.[9]

In Tables 6 and 7 are presented, respectively, the results of the analyses of variance in terms of gs (units of vertical acceleration) and Bs (number of bounces). Given are the means of control and experimental groups by check flights, and the p-values for the evaluation of each F. As in previous tables, variances not significant at the 5 per cent level of confidence are indicated as "n.s." (not significant) with the exception of the Methods variances, for which the confidence levels are indicated if less than .30.

__gs__. With reference to Table 6, it is evident that the only Methods variance for the g measure which might possibly be considered significant is that obtained in the fourth check flight administered by the flight examiner. The p-value lies between .10 and .05, the difference being in favor of the experimental group. It also is noteworthy that the pattern of differences over the four check flights administered by the flight examiner is similar to that found for the landing maneuver grades. That is, the control group shows better performance in the first and second check flights, whereas the experimental group is superior in the third and fourth check flights.

8(Continued) from the total population, thereby rendering untenable the procedure of summating chis squared or pooling of data. In general, particularly in so far as the pooled chi squared is concerned, this bias could be expected to result in somewhat spuriously high chis squared. It is significant to note that for none of these computations was the chi squared statistically significant.

[9] The data for the total "g" scores on the first pre-check flight did not meet the requirement that the frequencies in the cells be proportional, and analysis of variance therefore could not be applied to these data. It might be noted, however, that the difference between means is extremely small (see Table 6).

TABLE 6

RESULTS OF ANALYSES OF VARIANCE FOR TOTAL gs, SHOWING THE p-VALUES FOR EACH F CALCULATED AND OBTAINED MEANS FOR THE METHODS GROUPS

Source of Variation	Pre-check Flight (Instructors)				Check Flight (Examiner)			
	1**	2	3	4	1	2	3	4
Methods (M)		>.30	>.30	>.30	>.30	>.30	>.30	.10-.05
Instructors (I)		.05-.01	n.s.	.05-.01	n.s.	n.s.	n.s.	n.s.
Classes (C)		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
M x I		.05-.01	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
M x C		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
I x C		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
M x I x C		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Means of Total gs over Three Landings for Methods Groups								
Control	6.9	7.0*	6.8	6.3*	8.5*	8.1*	7.8	8.3
Experimental	6.7*	7.1	6.6*	6.4	8.6	8.4	7.5*	7.6*

*Group having better obtained mean performance.
**The data for the first pre-check flight were too disproportional to permit the use of analyses of variance in the manner in which it was used for the other pre-check flights and check flights.

TABLE 7

RESULTS OF ANALYSES OF VARIANCE FOR TOTAL Bs, SHOWING THE p-VALUES FOR EACH F CALCULATED AND OBTAINED MEANS FOR THE METHODS GROUPS

Source of Variation	Pre-check Flight (Instructors)				Check Flight (Examiner)			
	1	2	3	4	1	2	3	4
Methods (M)	.20-.10	$>$.30	.20-.10	$>$.30	$>$.30	$>$.30	$>$.30	$>$.30
Instructors (I)	$<$.01	$<$.01	.05-.01	$<$.05	n.s.	.05-.01	.05-.01	n.s.
Classes (C)	n.s.	n.s.	n.s.	.05-.01	n.s.	.05-.01	$<$.01	n.s.
M x I	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
M x C	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	$<$.01	n.s.
I x C	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
M x I x C	n.s.	n.s.	n.s.	n.s.	n.s.	.05-.01	n.s.	n.s.
Total Bs of Methods Groups								
Control	3.2	2.7*	2.8	1.5*	3.8	3.1	2.9	2.6
Experimental	2.3*	2.9	1.9*	1.7	3.6*	2.7*	2.5*	2.6

*Group having better obtained mean performance.

This patterning, however, is not indicated for the g measure as observed by the instructors during the pre-check flights.

It is evident, in any case, that the differences between mean performance of experimental and control groups is very small, the average difference per landing being in many cases less than the unit in which the vertical accelerometers were calibrated.[10]

It can be concluded, therefore, that meaningful differences between control and experimental groups in terms of the smoothness of landing, as measured by the number of g units produced by the landing, were not evident. It might be noted, however, that significant Instructor variances were evident for the second and fourth pre-check flights, which might indicate different observational practices on the part of different instructors, or possibly differences in performance peculiar to the students of given instructors. If this is the case, however, such differences were not evident in the check flight administered by the flight examiner. No meaningful conclusions can be drawn from the single significant Methods x Instructors interaction, except in so far as it, when viewed in connection with the significant Instructor variance, suggests the presence of some factor associated with instructors, which influenced to some degree the observed variability in performance of the subjects. It will be recalled in this connection that a significant Methods x Instructors variance was found for the landing maneuver grades in the third check flight.

Bs. Data on the number of bounces during the landing were analyzed by analysis of variance, the results of this analysis being summarized in Table 7. It is evident again that significant differences attributable to methods are not clearly evident, although two of the differences between methods (Pre-check Flights 1 and 3) are significant at between the .20 and .10 levels of confidence. In general, however, there seems no reason for the rejection of the hypothesis that there are no differences between control and experimental groups.

The fact, however, that significant variances attributable to instructors were evident on all four pre-check flights, and on two of the four check flights indicates the probability that the number of bounces a student makes in landing is a function of the training he receives from his instructor, and that the training in this respect varies from instructor to instructor. In this connection, however, the fact that at least part of this variability may be accounted for by differences in the observational procedures of the several instructors should not be overlooked.

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[10]These instruments were calibrated in terms of .1 g, and the means presented in Table 6 are the averages of g values summed over three landings. Thus, any difference between the mean totals presented less than .3, indicates that the mean difference per landing is less than .1.

The significant variances attributable to Classes found in the fourth pre-check flight and the second and third check flights might reflect the influence of some extraneous factor such as weather. The three significant first and second order interaction variances do not lend themselves to systematic interpretation in as much as no consistent trends are evident.

<u>Differences in Terms of gs and Bs Between Pre-check Flight and Check Flight Performances.</u> Examination of Tables 6 and 7 indicates that the mean performance of subjects, as measured, was somewhat poorer on flight checks administered by the examiner than on pre-check flights conducted by the instructors. For example, the mean number of gs produced by the landing on the check flight is in every case, and for both experimental and control groups, greater than the mean number of gs produced by the landings during the pre-check flight. Similarly, in regard to Bs, for all comparisons except one a larger mean number of bounces occurred during check flights than during pre-check flights.

In Table 8 are presented the differences in mean performance in terms of gs and Bs, respectively, between check flights and pre-check flights, the data from control and experimental groups being pooled. Although in terms of the pooled data, performance on the check flights was for every comparison poorer than on the pre-check flights, only two of the differences for Bs were significant at less than the 5 per cent level of confidence, and none of the differences for gs approach an acceptable level of confidence when evaluated by "t."

Had these differences been significant the evidence might, as suggested by the consistent differences in favor of the pre-check flights, have been considered to substantiate the general opinion that performances of student pilots are inferior on check flights administered by an examiner

TABLE 8

t-TEST FOR THE SIGNIFICANCE OF THE DIFFERENCES BETWEEN gs and Bs ASSIGNED BY EXAMINER AND INSTRUCTORS
(Data from Control and Experimental Groups have been Pooled)

Criterion	Check Flight Period	Mean Difference (Check Flight minus Pre-check Flight)	t	p
gs	1	1.75	.348	.80 - .70
	2	1.20	.257	.80 - .70
	3	.95	.281	.80 - .70
	4	1.60	.352	.80 - .70
Bs	1	.95	1.970	.05 - .02
	2	.10	.188	.80 - .70
	3	.35	1.050	.30 - .20
	4	1.00	3.037	.01 - .00

or inspector, than on flights conducted by their own instructor. However, a somewhat more plausible explanation of this trend lies in the fact that due to the inclusion of the photographic installation in the criterion plane, this plane in which the check flights were carried on was somewhat more overloaded than were the planes employed for instruction purposes. The fact that the criterion plane was somewhat heavier could be expected to cause slightly higher readings in terms of vertical acceleration on landing, as well as contributing to a greater number of bounces during this maneuver.

RESULTS: III. SPECIFIC CRITERION MEASURES RECORDED ONLY BY THE EXAMINER ON THE OSFI

The flight examiner recorded observations on a number of specific elements of flight performance pertaining to the maneuver "landing" through use of the Ohio State Flight Inventory. (These specific elements have been listed in Table 2.) As noted previously these observations recorded on the OSFI yielded information as to the "satisfactory" or "unsatisfactory" nature of performance in terms of these elements, as defined by standards developed in connection with the use of this inventory. Since the data were essentially dichotomous, analysis was made through application of chi squared to four-fold contingency tables as illustrated in Figure I. In this analysis data from each landing in each check flight were treated separately.

Chi squared was computed for each such table, using Yates' correction for small frequencies. These chi squared values, and the sums of the chis squared for each item, are presented in Table 9. Chi squared must be 3.841 or greater to be significant at the 5 per cent level of confidence for one degree of freedom. Of the total of 168 values[11] of chi squared computed, only 3 are significant at the 5 per cent level of confidence. These occur for Item 2, Check Flight 2, Landing 3; Item 7, Check Flight 2, Landing 2; and Item 8, Check Flight 4, Landing 1. Two of these show superiority on the part of the experimental group, and one shows superiority of the control group.

The last column to the right of the table shows the total chis squared for the 12 chis squared for each item.[12] These totals have 12 degrees of freedom. In order for chi squared to be significant at the 5 per cent level of confidence, chi squared would have to be 21.026 or greater. None of the total chis squared meet this criterion.

It is evident that with respect to the observations on elements of performance in the maneuver "landing," as recorded on the Ohio State Flight Inventory, there is no indication of systematic differences in proficiency between experimental and control subjects.

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[11]Fourteen items, 3 landings, and 4 check flights.

[12]This statistic was computed with the recognition that it was probably biased.

TABLE 9

CHIS SQUARED FOR EACH LANDING ON EACH CHECK FLIGHT FOR ELEMENTS OBSERVED AND RECORDED BY THE EXAMINER ON THE OHIO STATE FLIGHT INVENTORY

Item	Check Flight 1 Landing			Check Flight 2 Landing			Check Flight 3 Landing			Check Flight 4 Landing			Total
	1	2	3	1	2	3	1	2	3	1	2	3	
1. Direction during approach	.000	.517	.007	.593	.233	.950	.000	.000	.232	.000	.171	.000	2.703
2. Wing level during approach	.483	.000	.007	.000	.000	4.278**	.000	.000	.533	.442	.037	.075	5.855
3. Direction during roll	.000	.004	.007	.000	.167	.239	.868	.430	.000	.000	.000	.100	1.795
4. Wing level during roll	.000	.001	.000	.000	1.088	.853	2.794	.000	.001	1.641	.448	.000	6.826
5. Stalled or not stalled	.006	.000	.286	.207	2.159	2.058	.083	.089	.027	.220	.876	.959	6.970
6. Stalled smoothly or abruptly	.022	.000	.000	.000	.000	.063	.017	.559	.114	.585	1.036	.748	3.144
7. Speed constant or varied	.000	.000	.241	.025	4.278**	.000	.000	.089	.313	.147	.149	.000	5.242
8. Corrected or did not correct for drift when it occurred	.000	.037	1.598	1.149	.000	.066	1.267	.051	.813	4.585*	.890	2.984	13.44[illegible]
9. Leveled off at appropriate ht. or not	.636	.144	.002	1.036	.022	.000	.296	.000	.013	1.074	1.456	.158	4.837
10. Correct or incorrect ht. at stall	.225	.000	.001	1.143	.029	.847	.000	.829	.008	.274	.000	.149	3.505
11. Correct or incorrect clearance turn	.000	.000	.000	.000	.483	.000	.000	.000	.000	.000	.000	.000	.483
12. Observer did not or did assist	.022	.000	.000	.009	.965	.000	1.688	.882	.003	.000	.000	.000	3.569
13. Did or did not land in spot	.745	.013	.808	.000	.023	.000	.000	.257	.094	.325	.000	.075	2.340
14. Did or did not make good landing in terms of sequence of points contacting ground	.145	.680	.065	2.054	1.918	.000	.147	.274	1.247	.000	.146	.959	7.635

*Significant at 5% level and favoring control group. **Significant at 5% level and favoring experimental group.

RESULTS: IV. SPECIFIC CRITERION MEASURES FROM THE PHOTOGRAPHIC RECORDS

The specific criterion measures from the photographic record data sheets, listed in Table 2 as noted previously, were analyzed through application of chi squared, the application being identical with that employed for the OSFI items. The definitions of "satisfactory" and "unsatisfactory" performance in terms of each item are presented in Appendix 2.

There were twelve items on the photographic record data sheets for "landing" that could be meaningfully analyzed. Therefore a total of 144 chi squared values were computed.[13] The chi squared values for each four-fold contingency table are presented in Table 10. Only two of these values were significant, and none of the total chis squared, which undoubtedly are somewhat biased, are significant.

Therefore, as in the analysis of OSFI items, there is nothing to indicate the presence of systematic differences between experimental and control groups, in terms of the data yielded by the photographic records of flight performance during landing.

SUMMARY AND CONCLUSIONS

Primary Findings. In considering the results of the analyses of available data, it is evident that no systematic differences between experimental and control groups in terms of landing performance has been demonstrated, i.e., the hypothesis of no difference between the experimental and control groups cannot be rejected. Certain trends in the data might be taken as indicating slight superiority for the group receiving slow flight training (the experimental group). In this connection the "patterning" of landing maneuver grades, and certain other indices, could perhaps be considered as indicating slight superiority for the experimental group at the end of training, coupled with somewhat inferior performance early in training, which could be expected as a result of the initial effect of the experimental training procedure. However, contrary trends can also be found in the data, and without question unequivocal evaluation demands merely the statement that no systematic differences were indicated.

However, in connection with this interpretation a number of considerations should be mentioned. First, it might be pointed out that the experimental groups actually received less training in the normal power-off three-point landing (on which all students were tested) than did the control group. This point carries little weight, however, in as much as the purpose of the investigation was to determine whether the experimental training procedures were an effective substitute for the more usual instructional proce-

[13] Twelve items, 3 landings, 4 check flights

TABLE 10

CHIS SQUARED FOR EACH LANDING FOR EACH CHECK FLIGHT FOR ITEMS RECORDED ON PHOTOGRAPHIC RECORDS

Item	Check Flight 1 Landing			Check Flight 2 Landing			Check Flight 3 Landing			Check Flight 4 Landing			Total
	1	2	3	1	2	3	1	2	3	1	2	3	
1. Wings held level 5-10 sec. before contact	.088	.000	.119	.181	.000	.120	.000	.137	.260	.000	.000	.043	.948
2. Wings held level 0-5 sec. before contact	.000	.065	.383	.000	.078	.178	.181	1.433	.000	.288	2.138	.070	4.814
3. Wings held level at moment of landing	.005	.000	.021	.000	.000	.000	.000	.000	.000	.000	.000	.000	.026
4. Turn indicator 5-10 sec. before contact	.024	.802	.043	.000	.077	.989	.034	.000	1.501	.000	.000	.000	3.47[illegible]
5. Turn indicator 0-5 sec. before contact	.000	1.322	.061	2.378	6.233*	.000	.000	.000	.133	.000	.000	.213	10.3[illegible]
6. Turn indicator at moment of landing	.000	.047	.000	.078	.000	.000	.131	.189	.493	1.268	1.205	.310	3.721
7. Turn indicator 0-10 sec. after landing	.000	.215	.978	.000	.019	.537	.000	2.382	.118	.505	.512	.769	6.0[illegible]
8. Did or did not have stick full back at the moment of landing	.000	.718	.000	.252	.000	.039	.559	2.007	.013	.000	.000	1.534	5.122

TABLE 10 (Continued)

Item	Check Flight 1 Landing 1	Check Flight 1 Landing 2	Check Flight 1 Landing 3	Check Flight 2 Landing 1	Check Flight 2 Landing 2	Check Flight 2 Landing 3	Check Flight 3 Landing 1	Check Flight 3 Landing 2	Check Flight 3 Landing 3	Check Flight 4 Landing 1	Check Flight 4 Landing 2	Check Flight 4 Landing 3	Total
9. Did or did not have stick full back 0-10 sec. after contact	.894	.245	.331	.000	.057	1.438	.000	.352	.028	.449	.225	.000	4.019
10. Change in angle of attack 5-10 sec. before contact. Smooth or irregular	.579	.000	.000	.155	.000	.000	.857	6.947**	.000	.312	.000	.219	9.069
11. Change in angle of attack 0-5 sec. before contact. Smooth or irregular	.535	.000	.017	.024	.098	.000	.908	.306	.000	.132	.017	.000	2.037
12. Ball bank at moment of landing	.154	.033	.113	1.350	.012	.094	.000	.000	.000	.000	.000	.680	2.436

*Significant at 5% level and favoring control group. **Significant at 5% level and favoring experimental group.

dures in the normal power-off landing.

Second, the possibility should be recognized that the effect of the special slow flight instruction in landing might not become manifest until later in training.[14] While this might be true, and is perhaps suggested by the "patterning" of measures discussed earlier, it is again of little practical importance at least as far as the private pilot is concerned. Most student pilots make their first attempt to pass the private pilot flight test shortly after thirty-five hours of training. To be of practical value, any new method of teaching landings might reasonably be expected to demonstrate its efficacy before this time.

Third, it is not impossible that there exists a "true" difference in favor of one of the methods which was not measurable by the present investigation, either because of inadequacies in the design of the experiment and in the criteria themselves, or as a result of large variability in the performances as measured which obscured the "true" differences, rendering them not statistically significant.[15] In connection with this point an important qualification of the apparently negative results of the experiment itself should be emphasized.

The slow flight instructional procedure for the maneuver "landing," as employed in this investigation, was developed apparently independently by several flight instructors in the field on the basis of their actual day-to-day experience in teaching people how to fly. They, and other instructors who have employed the procedure, have reported on the basis of extensive use of the technique, that it has proved effective in teaching their student pilots how to land.[16] Because of the fact that the efficacy of the procedure may have been obscured by limitations in the design of the experiment, it cannot be concluded, although the experimental results were negative, that empirical evidence favoring the technique is necessarily unfounded and should be dismissed. The experimental evidence does not indicate that the slow flight training prodedure in landing is less effective than the conventional instruction procedure. Further experimentation

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[14] It will be recalled that the flight testing of subjects covered only the first 35 hours of training.

[15] If this were the case and if, as might be expected, variability among students grows less as training progresses, significant differences between experimental and control subjects might become evident later in training. It should be noted, however, that the absolute differences between mean performance of experimental and control groups, respectively, were in most cases not large.

[16] This training procedure was described, by a flight instructor, to Dr. Dean R. Brimhall, Director of Research, Civil Aeronautics Administration, who was instrumental in the development of this research project. Moreover, the advantages of the technique were reported by a number of flight instructors who responded to a survey of effective teaching techniques employed by flight instructors. Furthermore, the consensus of a group of experts who evaluated the techniques submitted during this survey was that the procedure is sound. (*Op. cit.*, see footnote 1.)

seems desirable, particularly in view of the favorable response to the procedure by many of those who have used it.

Secondary Findings. Consideration of the variances attributable to variables other than Methods (indicated in the analyses of those measures treated by analysis of variance) yield a number of implications. The significant variances attributable to the instructor variable were found in the analysis of data from one or more check flights for the criteria: "landing maneuver grades (assigned by the instructor) during pre-check flights," "gs on the pre-check flights," "Bs on the pre-check flights," and "Bs on the check flights." It is noteworthy that three of these significant Instructor variances were found in terms of criterion measures assigned by the instructor on pre-check flights. This suggests that differences in evaluative standards and observational procedures comprise an important source of variation in experimental investigations of this sort. The fact should not be overlooked, however, that such differences may also be due to differences in the instructional procedures of the several instructors. That this may be the case in connection, at least, with the number of bounces evident on landing is suggested by the fact that significant Instructor variance was indicated not only in terms of the measures obtained by the instructors during the pre-check flights, but also during the check flights administered by the flight examiner. Certainly it can be said without equivocation that more variance in this investigation was attributable to Instructors than to Methods.

Some evidence of variance attributable to "Class" was indicated by the analyses, five Class variances being significant, and it is possible that the weather factor may have been at least in part responsible. The data do not permit unequivocal interpretation of the significant interactions of Methods by Instructors, and Methods by Classes. There is a suggestion, however, that the experimental procedure was employed somewhat more effectively by certain instructors than by others, an implication which, although not out of line with expectation, is of some practical importance. These secondary findings, however, are of particular interest in connection with the development and design of future investigations of this type.

APPENDIX 1

SUMMARY OF EXPERIMENTAL PROCEDURES

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SUMMARY OF EXPERIMENTAL PROCEDURES[17]

Instructors of experimental students will make it a point during early stages of training, when the instructor makes the actual take-off and landing, to be certain that one-half of the landings are power approaches to the field; the other half shall be the normal power-off glide approach.

During the indoctrination, prior to the initiation of take-off and landing, students shall be trained in slow flying at altitudes sufficient to perform stalls safely; that is, well above 1500 feet. This procedure involves the gradual retardation of the throttle in straight and level flying requiring an increasing amount of elevator pressure to maintain altitude. Reduction of throttle then shall be carried out progressively, culminating in the actual stall. The gradual reduction in power should develop awareness of changes in "feel" of the controls and difference in response of the airplane to control movement. Stretching out the approach to the stall in this fashion will give the student a longer interval than is now available to develop awareness of changes in "feel."

The first two hours of landing practice shall consist entirely of power-approach landings. On every third power-approach landing, the instructor shall immediately open the throttle in such a manner that the student shall get the plane into the air off the runway and be required to hold the plane in the air off the runway. During this time the instructor will vary the throttle in such a way that the student will have to compensate for the changes in power by adequate use of elevators. The instructor must make certain that this practice shall be terminated and full power applied in time for a safe take-off with adequate altitude to clear any obstacles [18] (The 5000 foot runway at the Municipal field and the excellent cooperation which we have with the control tower will make possible the execution of such an experiment. As soon as the turf is in condition for use by light planes, such practice will be carried on over the turf, adjacent to, rather than over the runway)

The pilot's instrument panel shall be so arranged that at the initiation of the landing approach the instructor shall cover all instruments except the tachometer and the oil temperature and pressure gauges. The remainder of the allotted time in Stage A, for take-off and landing practices, shall consist of the normal 90° and 180° approaches in a power-off glide.

As soon as the student has soloed he then enters Stage B of his flight training. One hour of the two hours of dual time allowed in the approved

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[17] This appendix is an excerpt from the original design of the experiment, submitted for the staff of the Institute of Aviation Psychology by Robert Y. Walker, Director, October 23, 1944.

[18] It should be noted that an actual landing was not made.

curricula for precision landing practice shall consist of power approach practice.

Power approaches or slow flying with the instruments covered shall be performed ONLY UNDER DUAL FLIGHT and in no case shall be performed during solo flight.

After completion of seventeen hours of instruction (including check flights), the training of both experimental and control students shall be identical.

APPENDIX 2

CUT-OFF POINTS FOR OSFI AND PHOTOGRAPHIC RECORD DATA SHEET ITEMS

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CUT-OFF POINTS FOR OSFI AND PHOTOGRAPHIC RECORD DATA SHEET ITEMS

Ohio State Flight Inventory

Item	Cut-off
Direction during approach was constant or varied.	Constant = variation of 5° or less; Varied = variation greater than 5°.
Wing level during approach was constant or varied.	Constant = variation of 5° or less; Varied = variation greater than 5°.
Direction during roll was constant or varied	Constant = variation of 5° or less; Varied = variation greater than 5°.
Wing level during roll was constant or varied.	Constant = variation of 5° or less; Varied = variation greater than 5°.
Did or did not stall.	Judgment made by flight examiner.
Stalled smoothly or abruptly in those cases in which stall took place.	Judgment made by flight examiner.
Speed constant or varied.	Constant = variation of 5 m.p.h. or less; Varied = variation greater than 5 m.p.h.
Did or did not correct for drift when it occurred.	Judgment made by flight examiner.
Did or did not level off at the appropriate height.	Judgment made by flight examiner.
Height above ground at stall correct or incorrect.	Judgment made by flight examiner.
Made correct or incorrect clearance turns.	Judgment made by flight examiner.
Observer did not or did assist in the landing.	Judgment made by flight examiner.
Did or did not land in spot.	Judgment made by flight examiner.
Did or did not make a good landing in terms of the sequence of points contacting the ground.	Good = right and left wheels and tail made simultaneous contact with ground; or tail made contact first, and right and left wheels contacted the ground simultaneously. Bad = other types of landing.

Photographic Records

Item	Cut-off
Wings were held level or not level 5-10 seconds before contact.	Level = deviation on artificial horizon from horizontal of 5° or less; Not level = deviation on artificial horizon from horizontal greater than 5°.
Wings were held level or not level 0-5 seconds before contact	Level = deviation on artificial horizon from horizontal of 5° or less; Not level = deviation on artificial horizon from horizontal greater than 5°.
Wings were held level or not level at the moment of landing.	Level = deviation on artificial horizon from horizontal of 5° or less; Not level = deviation on artificial horizon from horizontal greater than 5°.
Turn indicator reading was satisfactory or unsatisfactory 5-10 seconds before contact.	Satisfactory = no turn right or left greater than "degree 0"[19] on turn indicator; Unsatisfactory = turn right or left greater than "degree 0" on turn indicator.
Turn indicator reading was satisfactory or unsatisfactory 0-5 seconds before contact.	Satisfactory = no turn right or left greater than "degree 0" on turn indicator; Unsatisfactory = turn right or left greater than "degree 0" on turn indicator.
Turn indicator reading was satisfactory or unsatisfactory at the moment of landing.	Satisfactory = no turn right or left greater than "degree 0" on turn indicator; Unsatisfactory = turn right or left greater than "degree 0" on turn indicator.
Turn indicator reading was satisfactory or unsatisfactory 0-10 seconds after contact.	Satisfactory = no turn right or left greater than "degree 0" on turn indicator; Unsatisfactory = turn right or left greater than "degree 0" on turn indicator.
Did or did not have the stick full back at the moment of landing.	Based on control indicator readings.
Did or did not have the stick full back 0-10 seconds after contact.	Based on control indicator readings.

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19 Variations of "degree 0" were defined as excursions of the turn indicator pointer less than one-half of the width of this pointer.

Photographic Records (Continued)

Item	Cut-off
Change in angle of attack was smooth or irregular 5-10 seconds before contact.	Read from angle-of-attack indicator.
Change in angle of attack was smooth or irregular 0-5 seconds before contact.	Read from angle-of-attack indicator.
Ball bank reading was satisfactory or unsatisfactory at moment of landing.	Satisfactory = excursion of ball one unit or less from center;[20] Unsatisfactory = excursion of ball greater than one unit from center.

[20]Excursion in which not more than one-half of the ball was outside the central markers or "lubber-lines" of the instrument.

APPENDIX 3

SEQUENCE OF MANEUVERS IN THE CHECK FLIGHTS

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SEQUENCE OF MANEUVERS IN THE CHECK FLIGHTS

No.	Maneuver	Check Flight No.: 1 Flown at: 7 hrs.	2 15 hrs.	3 25 hrs.	4 32 hrs.
1.	Taxi	x	x	x	x
2.	Take-off	x	x	x	x*
3.	Straight and Level	x	x	x	x
4.	Shallow 8s around Pylon		x		
5.	Medium 8s around Pylon			x	x
6.	Straight Climb	x	x	x	x*
7.	L 90° Climbing Turn	x	x	x	x
8.	L 90° Turn - 30° Bank	x	x	x	x
9.	R 90° Turn - 30° Bank	x	x	x	x
10.	L 360° Turn - Steep Bank		x	x	x*
11.	R 360° Turn - Steep Bank		x	x	x*
12.	Normal Power-off Stall	x*	x*	x*	x*
13.	Normal Power-off Stall	x*	x*	x*	x*
14.	Normal Power-off Stall	x*	x*	x*	x*
15.	Straight Glide	x	x	x	x*
16.	90° L Gliding Turn	x	x	x	x*
17.	Forward Slip	x	x	x	x
18.	Landing	x*	x*	x*	x*
19.	Landing	x*	x*	x*	x*
20.	Landing	x*	x*	x*	x*
	Total	16	19	19	19

Explanation: The "x" indicates the several maneuvers which are tested on the respective check flights. Those followed by an asterisk (*) indicate that a camera record will be taken. The photographic records of performance during Maneuvers 12, 13, and 14 were not employed in the analysis discussed in this report.