AN ANALYSIS OF GRAPHIC RECORDS OF PILOT PERFORMANCE OBTAINED BY MEANS OF THE R-S RIDE RECORDER

PART II

Quantitative Evaluation of Pilot Performance on 720° Power Turns

by

Oscar Backstrom, Jr.

and

Morris S. Viteles

A report of a study conducted at the University of Pennsylvania, Philadelphia, Pennsylvania, on records collected at Tulane University, New Orleans, Louisiana, by means of grants-in-aid from the National Research Council Committee on Selection and Training of Aircraft Pilots from funds provided by the Civil Aeronautics Administration.

January 1946

CIVIL AERONAUTICS ADMINISTRATION
Division of Research
Report No. 55
Washington, D. C.

National Research Council

Committee on Selection and Training of Aircraft Pilots

Executive Subcommittee

M. S. Viteles, Chairman

E. C. Andrus

C. W. Bray

D. R. Brimhall

J. W. Dunlap

J. C. Flanagan

W. R. Miles

P. J. Rulon

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 18, 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 An Analysis of Graphic Records of Pilot Performance Obtained by Means of the H-S Ride Recorder, by Oscar Backstrom, Jr., and Morris S. Viteles. 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 issued by the Division of Research, Civil Aeronautics Administration.

The report reflects the interest of the Committee on Selection and Training of Aircraft Pilots in arriving at objective and reliable measures of pilot performance. It describes methods for scoring graphic records, obtained through the use of a commercial flight recording instrument, as a means of arriving at quantitative evaluations of flight performance. Of particular interest are the comparisons between the qualitative and quantitative methods for analyzing graphic records and the discussion of the relative practical effectiveness and cost of these two methods.

Cordially yours,

M. Viteles

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

MSV:pd

PREFACE

In the search for objective measures of pilot efficiency the attention of the Committee on Selection and Training of Aircraft Pilots was early directed towards instruments, already in existence, designed to record graphically plane performance and control movements. While such flight recorders, including the Friez Analyzer and the R-S Ride Recorder, were intended primarily for use in investigating the influence of design on plane performance, it nevertheless seemed that they might also serve a useful purpose in the evaluation of flight performance in psychological experimentation. These instruments were therefore procured and subjected to experimental study at Tulane University, under the direction of Dr. H. M. Johnson;[1] at Harvard University, by Dr. R. A. McFarland and Dr. A. H. Holway;[2] at the University of Maryland, by Dr. J. G. Jenkins and Dr. R. M. Bellows;[3] at the University of Pennsylvania, by Dr. M. S. Viteles and Mr. Oscar Backstrom, Jr.

Records procured through the use of the R-S Ride Recorder by the Tulane University group were analyzed at the University of Pennsylvania with the view of determining the usefulness of both qualitative estimates of such recordings and of quantitative indices as means of discriminating levels of proficiency in flight performance. The findings of the qualitative analysis,[4] furnished evidence of a relationship between qualitative ratings of R-S Ride Recorder records of right 720° power turns and pilot skill as expressed in flying time. Tentative pattern scales were prepared as aids in rating performances on the 720° power turns and as a prototype of similar scales for other maneuvers. However, the results were not adequate for demonstrating definitively the existence of this relationship or for passing final judgment on the usefulness of qualitative estimates of graphic records as indicators of pilot skill.

The qualitative analysis of graphic recordings was initially viewed chiefly as a source of criterion data. As the investigation progressed, it became increasingly apparent that a suitably designed graphic recorder might prove to be an extremely useful aid to training, since an instrument

---

[1]See Part II of the study: 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.

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

[3]Bellows, R. M. Graphic investigation of flight performance. September 1940. Progress report in the files of the NRC Committee on Selection and Training of Aircraft Pilots,

[4]Viteles, M. S. & 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

providing records of control movements, as well as of airplane attitudes, could be used to advantage in demonstrating to student pilots, and also to instructors, errors in handling the controls and resulting faults in flight performance.

The qualitative analysis was supplemented by a detailed quantitative analysis of 720° power turns which is described in the present report. This analysis was arduous and time consuming even though limited to one of the maneuvers included in a flight examination. In part because of the small number of cases, the results of this analysis, as that of the qualitative study of graphic records, must be viewed as preliminary in character. As a matter of fact, the entire study and report in which it is described are probably of greater significance in terms of methodology than in terms of final and immediate application of outcomes. So, for example, the possibility of arriving at quantitative indices is clearly indicated in the results of the study. Moreover, the results suggest that carefully derived quantitative indices can serve to differentiate student pilots from licensed pilots and instructors who have had many hours of flying time. The possible usefulness of cutting scores in setting off criterion groups with various levels of skill is demonstrated. However, the immediate applicability of such findings is limited by wide differences among indices with respect to consistency in the measurement of flight performance on successive flights and by other factors which create a need for further investigation before final decisions can be made with respect to the research use of such instruments.

Since the study has involved the use of both qualitative and quantitative techniques for the analysis of graphic recordings, it seems appropriate to ask whether the quantitative method is sufficiently superior to the qualitative method in terms of providing criterion data or in terms of field use for training purposes to warrant the highly increased expenditure of time, manpower, and funds involved in the use of the quantitative approach.

This question has been given careful consideration, particularly in discussions with Captain J. G. Jenkins, USNR, who reviewed both this and the earlier report dealing with the analysis of graphic recordings. It appears reasonable to summarize the answers to the above question as follows:

1. (a) The qualitative method appears to be more useful than the quantitative approach <u>as a training aid</u>. For example, qualitative analysis of records of control movements may be used to point out to a student his faults in "riding" the rudder, in failing to use enough rudder; in faulty coordination between aileron and rudder, in turns, etc. With the aid of flight records, it can be clearly and unequivocally demonstrated to the student that when he failed to use enough rudder into a turn he slipped extensively; when he used too much rudder, he skidded extensively; when his rudder adjustment was approximately correct, he entered the turn in lateral balance, or with at most a slight slip or skid, and so

on. At the same time, correct adjustments may be demonstrated in a particularly impressive manner if instructor and student alternate in performing a given maneuver.

(b) The qualitative method has a particular advantage over the quantitative in that the recordings may be inspected and analyzed immediately upon the completion of the flight. Considerable time would be required for the computation of the quantitative indices which would be no more useful than qualitative indices in reviewing performance of the student pilot during training.

2. The usefulness of the quantitative method as a research tool remains indeterminant until its applicability to such relatively non-patterned maneuvers as straight and level flight, normal turns, normal climbs, and normal glides is further investigated. There is evidence from other studies that patterns of performance in such maneuvers are clearly revealed on the graphic recordings and may be subjected to qualitative evaluation by means of pattern scales such as are described in the earlier report from the University of Pennsylvania Project.

3. From the administrative viewpoint, the staff requirements and items of cost for the use of the quantitative method are invariably greater than those involved in the use of the qualitative method.

Apart from the findings gathered in the qualitative and quantitative analyses of graphic recordings, the studies have been useful in providing facts which were employed in the development of a new improved flight recorder known as the CAA-NRC Flight Recorder.[5]

In presenting this report it should be pointed out that it is the outcome of collaborative effort. Dr. H. M. Johnson and P. W. Cobb, Tulane University, supervised the collection of graphic records at the New Orleans Airport, and contributed much in the way of suggestions with respect to the treatment of records. Vidkunn Coucheron-Jarl assisted in the collection and identification of the records. The statistical treatment of Part I of this report was checked by Dr. M. G. Preston, University of Pennsylvania. The report was reviewed for publication by J. G. Jenkins, Captain, USNR, Psychological Section, Aviation Medicine Division, Bureau of Medicine and Surgery, U. S. Navy. Special acknowledgment is due to Dr. A. S. Thompson, formerly of the University of Pennsylvania, now at Vanderbilt University, who, as a member of the Editorial staff of the Committee on Selection and Training of Aircraft Pilots, prepared the report in its present form on the basis of a much longer report as originally written by the authors.

University of Pennsylvania
Philadelphia, Pennsylvania
12/28/45

Morris S. Viteles
Project Director

---

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

CONTENTS

CONTENTS (Continued)

SUMMARY

This report presents a detailed discussion of quantitative techniques used in the evaluation of graphic records of flight performance secured by means of the R-S Ride Recorder. Records of the right 720° power turn of three standard flights and of the left 720° power turn for the first and third of these flights were projected at a magnification of 5 and scaled at an arbitrarily established time interval of 0.8 second. The procedure gave measurements of the load factor or "vertical acceleration" trace, the left-wing-low trace, and the right-wing-low trace from which were derived quantitative indices of pilot performance. Graphic records for a total of 28 pilots, including 10 primary C.P.T. students, 10 recently licensed private pilots and 8 re-rated instructors, were analyzed in this investigation.

In all, 31 quantitative indices were developed, descriptive of various aspects of pilot performance with respect to accuracy and consistency of bank, maintenance of lateral balance, and time consumed in executing the 720° power turn.

Intra-group differences between mean scores on the left and right 720° power turn were investigated for each of the three experimental groups (students, private pilots and re-rated instructors) by means of t tests for matched groups. Ten of the 31 quantitative indices were employed in this investigation. Intra-group differences were also investigated with respect to slipping and skidding.

Inter-group differences among mean scores of the elementary students, private pilots, and re-rated instructors were analyzed by means of t tests for unmatched groups. Each of the 31 quantitative indices for both the right and left turns was included in this analysis.

A preliminary investigation, employing 4 of the 31 indices, was made to determine the value of using cutting scores for the differentiation of levels of flight experience.

Lastly, a separate analysis was made of 5 of the 31 indices to study the reliability of scores on flights flown in immediate succession.

The results of these analyses yielded the following general findings:

1. Within each of the three experimental groups (elementary students, private pilots, and re-rated instructors) differences were found between the left and right turns with respect to the maintenance of lateral balance. These differences are statistically significant in the case of the students and private pilots; in the case of instructors, the differences are in general not significant, but consistent.

2. Differences between left and right turn performance may be summarized as follows:

   a. Each group slips to a greater average magnitude, and for a greater proportion of time, on the right turn than on the left.

b. Each group skids to a greater average magnitude, and for a greater proportion of time, on the left turn than on the right.

c. Each group exhibits lateral imbalance (slipping plus skidding) to a greater average magnitude, and for a greater proportion of time, on the right turn than on the left.

3. Differences in performance between left and right turns may be explained in terms of two experimentally confirmed tendencies, right-wing-low tendency, and greater proneness of all pilots to slipping than to skidding. The greater proneness to slipping than to skidding resides in the subjects while the right-wing-low tendency may reside either in the subjects or in the aerodynamic characteristics of the airplane used in the research. The results are not adequate for unequivocal determination of the relative responsibility of subjects and airplane for the right-wing-low tendency. However, the tendency is almost universal among the 28 pilots studied.

These intra-group trends are of importance in the interpretation of differences in performance among groups of varying experience levels.

4. The three experimental groups differed among themselves, in terms of the quantitative indices, as follows:

a. Elementary students were consistently and significantly differentiated by several indices only from the private pilots; by other indices only from the instructors; and by other indices from both. The private pilots were not significantly and consistently differentiated from instructors on either the left or right turn by any of the 31 indices developed in this study.

b. In each case of significant differentiation, the students' mean score was lower with respect to proficiency in executing the maneuver as prescribed.

c. Elementary students were consistently and significantly discriminated from the other two groups chiefly by indices relating to the maintenance of lateral balance. Although one index relating to accuracy of bank (the mean "proper" bank) differentiated the students from the instructors on the left turn, the indices dealing with fluctuation of bank and time consumed in executing the turn did not differentiate the experimental groups. Failure of the bank indices to discriminate among experimental groups may be due, in part, to the influence of errors arising from a relatively inaccurate accelerometer for the measurement of load factor, or "vertical acceleration." Comparisons employing the total time of the maneuver as an index, while failing to demonstrate consistent and significant differentiation, indicate that a "trend of separation" of the groups exists with respect to this variable, and that it may be profitable in future research with other maneuvers to investigate time measures as a means of discriminating experience levels.

d. Differentiation of experimental groups on both left and right turns occurred only in the case of indices dealing with the time or proportion of time spent in faults of lateral balance (slipping, skidding, and lateral imbalance). The remainder of the indices dealing with lateral balance differentiated the experimental groups on the right turn, but not on the left turn. These discrepancies may be accounted for by considering the differential effects of the previously noted intra-group tendencies on each group of subjects.

5. In general, the instructor group exhibited the best performance and the students the poorest. The private pilots were more frequently differentiated from the students than from the instructors, suggesting that the aspects of pilot skill measured by the indices reach a relatively high level of performance during the training program required for private pilot certification.

6. For left and right turns, respectively, satisfactory cutting scores were obtained on several indices, considering a satisfactory cutting score as one which accepts a group including a high percentage of instructors and private pilots and a relatively low percentage of students. In many instances it was impossible to obtain cutting scores which would accept or reject the same individuals on both left and right turns, indicating that the indices used in this investigation refer only to small segments of performance, and "place" individuals only with respect to a single maneuver. For widespread field application of quantitative indices in the placement of individuals according to levels of flying experience, it would be necessary to combine scores by appropriate procedures in order to obtain a score representative of the performance of a group of fundamental maneuvers, or of an entire flight.

7. A study of 5 selected indices revealed wide differences among the indices with respect to consistency of pilot performance on successive flights, inter-flight correlations ranging from .09 to .84. In general, the slip score exhibited higher reliability than the skid score, indices on the right turn higher than those on the left turn, and those dealing with magnitude of the fault higher than those dealing with time

AN ANALYSIS OF GRAPHIC RECORDS OF PILOT PERFORMANCE
OBTAINED BY MEANS OF THE R-S RIDE RECORDER

PART II

Quantitative Evaluation of Pilot Performance on 720° Power Turns

INTRODUCTION

Part I of this report[1] presented a description and evaluation of various qualitative techniques for the evaluation of graphic records of flight performance secured by means of the R-S Ride Recorder. Part II describes an extension of the investigation in order to develop quantitative indices of flight performance and to evaluate their usefulness as a possible source of criterion data.

The primary objectives in this investigation of the application of quantitative techniques in the analysis of graphic records may be summarized as follows:

1. To determine the suitability of quantitative indices, derived from R-S Ride Recorder records, in differentiating the skill in executing 720° power turns of groups of elementary students, private pilots, and re-rated instructors characterized by wide differences in number of hours of flying experience.

2. To apply these indices to the investigation of certain specific problems, namely:

   a. Intra-group differences in performance on left and right 720° power turns.

   b. Intra-group differences in slipping and skidding on both left and right turns.

   c. Reliability of indices computed from records of flights flown in immediate succession.

3. To investigate the utility of cutting scores applied to such indices in identifying levels of pilot experience, with a view to the ultimate use of such indices as predictors of pilot performance.

DESIGN AND PROCEDURES

Maneuvers Selected for Analysis. The sample quantitative analysis included left and right 720° power turns. The right 720° power turns of

---

[1]Viteles, M. S. and Backstrom, Oscar, 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.

three flights were used in all comparisons, with the exception of the section of the study dealing with the relation between performance on the right and left turns. In this case, for purposes of economy, the right 720° power turns of only the first and third flights and the corresponding left 720° power turns were employed.

Traces of the R-S Ride Recorder Chart Employed in the Quantitative Analysis. The traces of the R-S Ride Recorder chart used in obtaining data for the derivation of quantitative indices were the same as those employed to derive the items on which the qualitative ratings were based: namely, the load factor trace, the left-wing-low trace, and the right-wing-low trace.[2]

As described in the Supplemental Report included in Part I, the load factor trace can be measured in units of g which may be converted into angular values of "proper" bank;[3] and the wing-low-traces may be measured in arbitrary units representative of and analogous to deviations of the ball from the center position of a ball-bank indicator.[4]

Measurement of the Records by Projection. Accurate measurement of the graphic records was impossible without magnification for two reasons: first, the low paper speed at which the records were taken suppressed the details; and second, the vertical chart space of any one trace is not great enough to permit accurate, fine reading of any of the three effects. In order to secure the quantitative readings, the records were projected onto an adjustable screen by means of a reflectoscope. The screen (covered with graph paper ruled 10 by 10 to the inch) was mounted in a swivel joint to facilitate the adjustment of reference lines of the projected chart to the reference lines of the screen. A magnification of 5 was selected as the most practicable for purposes of this study.

A plastic scale was constructed in order to synchronize the traces in making the readings. The records were then read as follows:

1. The reader, having aligned the image of the chart properly with the reference lines of the screen, brought the plastic scale to the beginning of the maneuver as shown by the initial signal mark on the record. The intersection of each of the three traces with its respective scale arc was then read at this zero (or origin) space.

2. Readings were then made at each horizontal screen space (representing 0.8 second) up to and including the final signal mark. The readings were called off in units of vertical screen spaces to a recorder, who entered them on the data sheet (see Appendix C).

---

[2]These are the only traces provided by the R-S Ride Recorder which are amenable to meaningful quantitative measurement, since neither the pitch-and-longitudinal-acceleration trace nor the control movements traces supply meaningful quantitative data. See Viteles, M. S. and Backstrom, Oscar, Jr. Op. cit., pp. 189 ff.

[3]See Viteles, M. S., and Backstrom, Oscar, Jr. Ibid., p. 160.

[4]See Viteles, M. S., and Backstrom, Oscar, Jr. Ibid., p. 184.

Conversion of Chart Measurements into Values used for Deriving Indices. The measures in terms of vertical screen spaces were then converted into corresponding equivalents as shown in Table 1.

TABLE 1

SHOWING EQUIVALENTS OF CHART DISTANCE, SCREEN DISTANCE, AND QUANTITATIVE VALUES OF ITEMS DERIVABLE FROM THE R-S RIDE RECORDER CHART

Item Measured	Quantity	Chart Distance in Inches	Screen Distance in Spaces
Time	4.0 sec.	.10	5
Time	0.8 sec.	.02	1
Load Factor	0.1 g (static calibration)	.10	5
Load Factor	0.02 g (static calibration)	.02	1
Lateral Imbalance (left-or-right-wing-low)	2.0° or .035 g (static calibration)	.10	5
Lateral Imbalance	0.4° or .007 g (static calibration)	.02	1

The values of load factor in screen spaces were converted on the data sheet to values of load factor in g. These values were in turn converted into values of "proper" bank.

The values of left-wing-low and right-wing-low were converted into values of slip and skid in degrees as measured by the static calibration of the lateral pendulums. It should be noted that these values of the slip and skid angle were not used in computing indices. They were used only as an intermediate step in obtaining values of "proper" bank (see Appendix C). In computing indices relating to lateral balance, the values of slip and skid were expressed in screen spaces.

Accuracy of Measurement. Accuracy of measurement was checked periodically.[5] This informal checking procedure demonstrated that all measurements are accurate within a range smaller than ±3.0 screen spaces, with the exception of a few readings of load factor. The absolute average of errors in reading any trace is less than 1 screen space; the algebraic average of errors in reading any trace approaches 0. Since the indices computed are derived from a large number of readings, this level of accuracy of single readings seemed quite satisfactory.

Development of Indices. Given the time history of a maneuver in terms of the above values, it was possible to devise quantitative indices descriptive of the pilot's proficiency in attaining and maintaining a prescribed bank throughout a turn and his proficiency in keeping the airplane in lateral balance. These indices, 31 in number, are described in detail later in the report (pages 4 to 13).

---

[5]For details of the measuring process see Appendix A.

Statistical Treatment. The following statistical techniques and procedures were utilized in the analysis of the data gathered in this investigation:

1. Student's t for matched groups of scores was employed (a) to determine if significant differences existed between slipping and skidding indices in each group of pilots (see Tables 3 and 4) and (b) to determine if significant differences existed between performance of the left and right turns in each group. Selected indices on left and right turns made during standard flights 1 and 3 were used in this analysis (see Table ?).

2. Student's t for unmatched groups of scores was employed to reveal the presence or absence of statistically significant differences among the mean scores of the three experimental groups on each of the 31 indices for both the right and left turns (see Tables 5, 6, 7, 8, 9, and 10).

3. In order to make a preliminary investigation of the utility of the quantitative indices in differentiating levels of pilot experience, distributions of scores of all subjects on selected indices for each turn were plotted, and cutting scores assigned in an attempt to segregate the experienced and inexperienced pilots (see Table 11).

4. Product-moment correlations were used to determine the variability of selected indices derived from records of flights flown in immediate succession. Scores of all subjects on selected indices on the left turn of Flight 1 were correlated with their scores on the left turn of Flight 3. Scores on these same indices on the right turns of Flights 1, 2, and 3 were also intercorrelated (see Table 12).

DESCRIPTION AND DISCUSSION OF THE QUANTITATIVE INDICES

Division of Each Turn into Entry, Turn Proper, and Recovery. In considering quantitative methods of expressing the proficiency of a pilot in attaining and maintaining a given bank, it is apparent that the pilot should not be held liable for deviations during the period he is achieving his bank during entry or leaving it during recovery. Each turn was therefore divided into three arbitrarily defined sections:

1. Entry -- that section of the turn between the initial signal indicating the beginning of the maneuver and the horizontal projection screen space at which a "proper" bank of 30° or greater[6] was first attained.

2. Recovery -- that section of the turn between the horizontal projection screen space at which a "proper" bank of 30° or greater was

---

[6] In projection of the record onto the graph-paper screen, the first point of attainment of a "proper" bank of exactly 30° might fall between the points at which readings were made.

last attained, and the final signal, indicating the end of the maneuver.

3. Turn proper -- that section of the turn between the first attainment of a "proper" bank of 30°, or greater, and the last attainment of a "proper" bank of 30°, or greater.

The value of 30° was selected for use in this study for the following reasons:

1. The value of the prescribed bank of 60° could not be employed because many subjects did not attain a bank of 60°.

2. The maximum bank attained during the maneuver could not be employed because many of the subjects did not attain their maximum bank until the turn was nearly completed.

3. Since it was desired to eliminate the factor of a reader's judgment, the procedure employed in the Sample Qualitative Analysis for delimiting the three sections[7] could not be used.

4. At the value of 30°, readings of "proper" bank become negligibly affected by errors of measurement and extraneous accelerations. Below the value of load factor corresponding to a "proper" bank of 30°, slight errors in reading the load factor trace, or slight errors in recording,[8] or both, may produce relatively large errors in the corresponding values of "proper" bank.[9] (It is to be noted that although errors of measurement may be expected to "average out" in the indices computed, errors due to the recording of extraneous accelerations might not.)

5. All subjects attained a "proper" bank of 30° on all turns (with the exception of one subject who misunderstood the instructions).

<u>Bank Indices</u>.[10] Indices based on "proper" bank readings are as follows:

---

[7] Viteles, M. S., and Backstrom, Oscar, Jr. <u>Op. cit</u>., pp. 19-20.

[8] For a detailed consideration of the accuracy of the accelerometer or load factor indicator, see Viteles, M. S., and Backstrom, Oscar, Jr. <u>Ibid</u>., pp. 171-178.

[9] The nature of the relation between load factor and "proper" bank is such that increments in load factor in the lower part of the range correspond to larger bank angles than equal increments in the upper part of the range. See Viteles, M. S., and Backstrom, Oscar, Jr. <u>Ibid</u>., p. 179.

[10] Difficulties encountered in the computation of the quantitative indices are described in detail in Appendix B.

1. <u>Mean "proper" bank</u>.[11] This index is the average of all readings (in degrees) of "proper" bank during the turn proper. As an indicator of the conformity of the attained "proper" bank to the prescribed bank this index is influenced by at least two factors: the ability of the pilot to estimate angles of bank correctly and his ability to maintain a given angle of bank.

2. <u>Fluctuation in "proper" bank</u>. Subjects may differ not only in the average bank attained, but also in the consistency with which they maintain each level of bank throughout the turn. Accordingly, an index was developed which would give a quantitative indication of the fluctuation in bank during the turn.[12] The index is an average (with correction) of the increments in "proper" bank from one reading to the next (so-called "stepwise deviations") during the turn proper. The increment of one reading over the preceding may be positive or negative, and these were recorded with regard to sign (see sample Quantitative Raw Data Sheet, Appendix C). In the computation of the index, however, signs were ignored, since an average of these algebraic values must approach zero, and since it was desired to measure fluctuation without regard to direction.

Index 2 was calculated by means of the following formula:

$$\text{Fluctuation in "proper" bank} = \bar{\delta} - \frac{\Delta_1 + \Delta_2}{N},$$

Where:

$\bar{\delta}$ = the average of the absolute values of the stepwise deviations in "proper" bank during the turn proper.

Δ_1 = the absolute difference between mean "proper" bank and the first reading of "proper" bank in the turn proper.

Δ_2 = the absolute difference between mean "proper" bank and the last reading of "proper" bank in the turn proper.

N = the number of stepwise deviations included in the turn proper.

By the above formula, a pilot can attain the perfect score of 0 only by holding a constant bank angle throughout the turn proper.

---

[11]The mean "proper" bank is used rather than mean deviation from the prescribed bank because the former is obtained directly from the values of "proper" bank. The mean deviation from the prescribed bank is given directly by subtraction of the mean "proper" bank from 60°. All values of the mean "proper" bank are less than 60°.

[12]It is to be noted that a measure of variability of a distribution of the "proper" bank readings, such as the standard deviation, cannot be employed for this purpose. The standard deviation would give a measure of the variability of a distribution of readings of bank about the mean bank, but would indicate nothing in regard to the temporal nature of this variability.

If the value of Index 2 were not corrected by subtraction of the expression $\Delta_1 + \Delta_2/N$ from $\emptyset$, subjects with higher mean "proper" banks would be "penalized"; in attaining and leaving the higher mean bank, their bank necessarily fluctuates more than that of subjects with lower mean banks.

Indices Relating to Lateral Balance. In terms of the practical problems of the pilot, it seemed desirable to investigate slipping and skidding separately. Indices were therefore developed to measure the several aspects in which slipping may vary and in like fashion to measure skidding. Since both slipping and skidding represent deviations from lateral balance, however, it was also desirable to investigate them not only separately, but also in combination, as manifestation of the general fault of lateral imbalance. Slipping and skidding were therefore combined to derive indices of lateral imbalance parallel to indices of slip and skid.

Slips and skids differ not only in the magnitude of the slip or skid, but also in the time spent in slipping or skidding. In the case of each fault (slipping, skidding, and lateral imbalance), therefore, "single-variable indices" were computed to measure the single variables of magnitude and time, and "composite" indices were computed to take account of both variables.

All indices relating to lateral balance were expressed in the units of projection screen spaces in which the readings were recorded on the Quantitative Raw Data Sheet.

1. Single-variable indices.

   a. Indices relating to Time Spent in Faults in Lateral Balance (Slipping, Skidding, and Lateral Imbalance). Time measurements were obtained from the graphic records by measuring along the base-line of the appropriate wing-low trace the length of chart during which the trace is off the base-line, or beyond a predetermined distance from the base-line.

   Indices relating to the time spent in faults in lateral balance computed in the course of this investigation included:

   (1) Time spent in slipping,

   (2) Time spent in skidding,

   (3) Time spent in lateral imbalance.

   The times noted above are absolute values. Since, however, one subject may spend more time in slipping than another subject merely because he spent more time in executing the maneuver, it was necessary also to investigate the following ratios:[13]

---

[13]Since an instructor in the field cannot conveniently make use of ratios, investigation of the actual time values was necessary to determine if the differences in time spent in slipping, skidding, and lateral imbalance were significant despite the effect of other variables.

(1) The proportion of time spent in slipping, i.e., time spent in slipping divided by the [illegible] of the maneuver.

(2) The proportion of time spent in skidding

(3) The proportion of time spent in lateral imbalance.

b. <u>Indices relating to Magnitude of Slipping, Skidding, and Lateral Imbalance</u>. The magnitude of slipping or skidding <u>at any single point in time</u> may easily be obtained from the R-S record by a single measurement of the height of the appropriate wing-low trace from its base-line. The simplicity of obtaining this information and its consequent possible utility in the field led to the computation of the following indices:

(1) Maximum magnitude of slip.

(2) Maximum magnitude of skid.

(3) Maximum magnitude of lateral imbalance.

Three other single-variable indices relating to magnitude, namely, average magnitude of slip, average magnitude of skid, and average magnitude of lateral imbalance, were also devised. These indices (expressed in vertical projection screen spaces) were defined as follows:

(1) Average magnitude of slip $= \dfrac{\Sigma \text{ slip readings (greater than 0)}}{\text{No. of slip readings (greater than 0)}}$

(2) Average magnitude of skid $= \dfrac{\Sigma \text{ skid readings (greater than 0)}}{\text{No. of skid readings (greater than 0)}}$

(3) Average magnitude of lateral imbalance $= \dfrac{\Sigma \text{ slip readings (greater than 0)} + \Sigma \text{ skid readings (greater than 0)}}{\text{No. of slip readings (greater than 0)} + \text{No. of skid readings (greater than 0)}}$

The latter three indices are too complex for ready calculation in the field. The average magnitude of slipping, skidding, and lateral imbalance, however, may be presumed to be more representative of the subject's performance than the maximum magnitude and are therefore preferable for purposes of research.

2. Composite Indices.

a. <u>Indices relating to the Time spent in Slipping, Skidding, or Lateral Imbalance beyond Certain "Critical" Magnitudes</u>. It seemed possible that the groups of subjects might be differentiated not only by the time spent in slipping, skidding, or lateral imbalance, but also by the time spent in slipping, skidding, or lateral imbalance beyond certain "critical" magnitudes. For example, two subjects, A and B, might spend exactly the same time in slipping, but all of subject A's slipping time might be spent in slips <u>below</u> a certain "critical" magnitude, and all subject B's slipping time in slips <u>beyond</u> this "critical" value. Indices based on this principle could be adapted for field use since critical values of slip and skid might be translated in terms of a parallel calibration on the ordinary ball-bank indicator. For example, a wing-low trace of 5 projection screen spaces in height is produced by a static inclination of 2° (see Table 1). If it should prove that the time spent in slips beyond a "critical" value of 5 projection screen spaces discriminates the experimental groups, the ball-bank indicator might then be calibrated by placing an appropriate mark in the position assumed by the ball when the airplane is statically inclined 2°.[14] In training, the instructor might then use this calibrated ball-bank in appraising the performance of the student.

From the Quantitative Raw Data Sheets, frequency distributions of the readings of slip and skid were prepared. These distributions were then examined and by inspection, several promising critical magnitudes were selected for statistical investigation. The following 12 indices were devised:

(1) Time spent in slipping at or beyond the "critical" level of 5 (vertical) projection screen spaces (5 vertical projection screen spaces corresponding to tilt of 2° by static calibration).

(2) Time spent in skidding at or beyond the "critical" level of 5 (vertical) projection screen spaces.

(3) Time spent in lateral imbalance at or beyond the "critical" level of 5 (vertical projection screen spaces.

(4) Time spent in slipping at or beyond the "critical" level of 10 (vertical) projection screen spaces (10 vertical projection screen spaces corresponding to tilt of 4° of static calibration).

(5) Time spent in skidding at or beyond the "critical" level of 10 (vertical) projection screen spaces.

---

[14]Since the effects of slipping and skidding are independent of the masses involved, the ball of the ball-bank indicator and the wing-low pendulums of the R-S Ride Recorder are subject to the same effects in the same amounts except for differences in damping. In the actual calibration of the ball-bank indicator in terms of "critical" magnitudes of slip or skid defined from graphic records, due regard would be taken of such differences in damping. For example, the damping factor of the ball-bank indicator might be considerably reduced (by reducing the density of the fluid through which the ball moves) in order to minimize the differences in damping. See Viteles, M. S., and Backstrom, Oscar, op. cit., p. 134

(6) Time spent in lateral imbalance at or beyond the "critical" level of 10 (vertical) projection screen spaces.

(7-12) Appropriate ratios for each of indices (1-6): namely, the ratio of each index to the time of the maneuver.

b. <u>Indices Taking Account of Both Magnitude and Time Spent in Slipping, Skidding, or Lateral Imbalance</u>. In the single-variable indices relating to time, the magnitude of each fault was disregarded, and conversely, in the single-variable indices relating to magnitude, the time spent in each fault is disregarded. In the composite indices relating to the time spent in the various faults beyond certain "critical" levels, one variable, time, is "sampled" at <u>selected values</u> of the other variable, magnitude. None of these indices is thus directly responsive to changes in both variables. It was sought, therefore, to devise indices whose values would depend directly on both time and magnitude and would change with changes in either time or magnitude. Such composite indices, taking full account of both time and magnitude, may be presumed to be the most "valid"[15] indices of proficiency in maintaining lateral balance, and accordingly the most pertinent for research aimed at describing the characteristics of the various groups of pilots. The following indices were derived:

(1) Slip score. The slip score is the sum of all readings of slip (expressed in vertical projection screen spaces) divided by the number of readings in the maneuver (the time of the maneuver in screen spaces). The slip score is thus the average magnitude of slip throughout the maneuver. As such, its value depends directly upon both the magnitude and time spent in slipping. For a maneuver of a given length the greater the magnitude of slip, the greater will be the sum of the slip readings; the longer the time spent in slipping, the greater will be the sum of the slip readings; and the greater will be the magnitude of the score.

(2) Skid score. A skid score representing the average magnitude of skidding throughout the maneuver was completed in similar fashions.

(3) Lateral imbalance score. The lateral imbalance score, representing the average magnitude of lateral imbalance throughout the maneuver was similarly completed. It is equal to the sum of the slip score and the skid score.

---

[15]"Valid" is employed here in the physical sense, i.e., descriptive of, and measuring, the physical events of deviations from lateral balance. The single-variable indices might prove to be equally as valid in a <u>statistical</u> sense, i.e., in discriminating the experimental groups.

<u>Indices Relating to the Time Consumed in Executing the Turn</u>. The following two indices were computed and investigated:

1. <u>Total Time of the Maneuver</u> (expressed in horizontal projection screen spaces). The total time of the maneuver is determined by a number of factors, including degree and steadiness of bank, degrees of turn, and rapidity of entry and recovery. It therefore, bears no simple relation to pilot skill. It was thought worth investigating, however, on the chance that it might differentiate the groups, and also because the information it yields would be useful in interpreting other indices, particularly those time items concerned with lateral imbalance.

2. Time between beginning signal and first attainment of a "proper" bank of 30° or greater. This index is the time consumed in the arbitrarily defined entry. It was thought that this index would be of particular interest in determining whether the time taken by more experienced pilots in rolling up to a "proper" bank of approximately 30° was less than the time required by the less experienced pilots.

<u>Summary List of the Indices</u>. For reference in tables and later discussions, the indices have been given index numbers and abbreviated titles. Following is a complete list of the 3[illegible] indices:

1. <u>Mean bank</u>, i.e., mean "proper" bank in degrees.

2. <u>Bank Fluctuation</u>, i.e., fluctuation in "proper" bank, expressed in degrees per 0.8 sec.

3. <u>Time to Attain Bank</u>, i.e., time, in horizontal projection screen spaces, between beginning signal and first attainment of a "proper" bank of 30°.

4. <u>Total Time</u>, i.e., total time of maneuver expressed in horizontal screen spaces.

5. <u>Slip Score</u>, i.e., average magnitude of slip throughout the maneuver, including 0 readings and expressed in vertical projection screen spaces.

6. <u>Average Slip Magnitude</u>, i.e., average magnitude of positive slip readings (excluding 0 readings), expressed in vertical projection screen spaces.

7. <u>Maximum Slip Magnitude</u>, i.e., maximum magnitude of slip, expressed in vertical projection screen spaces.

8. <u>Time Slipping</u>, i.e., [illegible] slipping, expressed in horizontal projection screen spaces.

9. <u>Per cent of Time Slipping</u>, [illegible] in slipping, divided by [illegible]

10. Time, Moderate Slip or Greater, i.e., time spent in slipping at or beyond the level of 5 vertical projection screen spaces.

11. Per cent Time, Moderate Slip or Greater, i.e., time spent in slipping at or beyond the level of 5 screen spaces, divided by total time of maneuver.

12. Time, Large Slips, i.e., time spent in slipping at or beyond the level of 10 vertical projection screen spaces.

13. Per cent Time, Large Slips, i.e., time spent in slipping at or beyond the level of 10 screen spaces, divided by total time.

14. Skid Score, i.e., average magnitude of skid throughout the maneuver (including 0 readings), expressed in vertical projection screen spaces.

15. Average Skid Magnitude, i.e., average magnitude of positive skid readings (excluding 0 readings), and expressed in vertical projection screen spaces.

16. Maximum Skid Magnitude, i.e., maximum magnitude of skid, expressed in vertical projection screen spaces.

17. Time Skidding, i.e., time spent in skidding, expressed in horizontal projection screen spaces.

18. Per cent Time Skidding, i.e., time spent in skidding, divided by total time of maneuver.

19. Time, Moderate Skid or Greater, i.e., time spent in skidding at or beyond the level of 5 vertical projection screen spaces.

20. Per cent Time, Moderate Skid or Greater, i.e., time spent in skidding at or beyond the level of 5 screen spaces, divided by total time of maneuver.

21. Time, Large Skids, i.e., time spent in skidding at or beyond the level of 10 vertical projection screen spaces.

22. Per cent Time, Large Skids, i.e., time spent in skidding at or beyond the level of 10 screen spaces, divided by total time of maneuver.

23. Lateral Imbalance Score, i.e., average magnitude of both slip and skid readings throughout the maneuver (including 0 readings), expressed in vertical projection screen spaces.

24. Average Lateral Imbalance Magnitude, i.e., average magnitude of both slip and skid readings (excluding 0 readings), expressed in vertical projection screen spaces.

25. Maximum Lateral Imbalance Magnitude, i.e., maximum magnitude of slip or skid readings, expressed in vertical projection screen spaces.

26. Time, Lateral Imbalance, i.e., time spent in both slipping and skidding, expressed in horizontal projection screen spaces.

27. Per cent Time, Lateral Imbalance, i.e., time spent in both slipping and skidding, divided by total time of maneuver.

28. Time, Moderate Lateral Imbalance or Greater, i.e., time spent in both slipping and skidding beyond the level of 5 vertical projection screen spaces.

29. Per cent Time, Moderate Lateral Imbalance or Greater, i.e., time spent in slipping and skidding beyond level of 5 vertical projection screen spaces, divided by total time of maneuver.

30. Time, Large Lateral Imbalance, i.e., time spent in slipping and skidding beyond level of 10 vertical projection screen spaces.

31. Per cent Time, Large Lateral Imbalance, i.e., time spent in slipping and skidding beyond level of 10 vertical projection screen spaces, divided by total time of maneuver

RESULTS

The results of most general interest are inter-group comparisons relating to the significance of the differences among mean scores of elementary students, private pilots, and re-rated instructors on each of the 31 indices. These results, however, may be adequately interpreted only with the knowledge of certain intra-group differences between performance on left turns and performance on right turns, and between slipping and skidding.

For convenience in discussion, therefore, the performance of each group on the left turn and right turn, respectively, and the performance with respect to slipping and skidding within each group will be considered first. Following this discussion, the differences in performance among the three experimental groups will be presented. In addition, there will be presented a discussion of cutting scores on several quantitative indices and data on the correlation between scores on successive flights.

Differences between Performance of Left and Right Turns for each Group. Comparisons were based on the mean scores of the left and right turns during Standard Flights 1 and 3.[16] Ten of the 31 indices were evaluated for

---

[16] Comparisons were not made for Flight 2 because the records of the left turn on this flight were not read.

[illegible] [17] The results of these analyses [illegible]

Table 2 presents the mean [illegible] for the right and left turns and the differences (L-R) between them. The column headed p_1 is the probability that the difference between each given pair of mean scores is attributable to chance. For those indices which are ratios, i.e., Indices 9, 18, and 27, based on per cent of time in slipping, skidding, and lateral imbalance, respectively, the p_1 value contains a spurious element due to spurious index correlation. When such spuriousness is present, a smaller difference between two mean scores will appear to be statistically significant by the test. For comparisons of these ratios, therefore, a second probability value (p_2), devoid of this spurious element, was derived. The p_2 value was computed for each comparison by examining the direction of the difference between each pair of matched scores and computing the probability that the observed number of + and - differences would appear by chance.[18]

Table 2 presents, for each comparison involving a ratio-index, the number of positive and negative differences between the matched pairs of raw scores.[19] In each case, a + sign indicates that the score for the left turn is higher. For example, in the comparison between the left and right scores of the 8 elementary students on the per cent of time spent in slipping on Flight 1 (see Table 2, Index 9), the left turn score of 1 student was greater, while the right turn scores of 7 students were greater than their left turn scores. The probability (p_2) that out of a group of 8 students, 7 would show a higher right turn score by chance alone is .03.

1. Significance of the Differences between Mean Scores. Employing the 5% level of significance, examination of Table 2 reveals the following:

---

[17] These 10 indices were considered the most pertinent for investigating the relative difficulty of the left and right turn, since they are the more fundamental of the 31 indices devised for measuring the performance with respect to "proper" bank and lateral balance. If differences between left and right turns were revealed in the case of these basic indices, investigation of the other indices would seem to be academic since the differential difficulty of the two turns would be established and objectively defined.

[18] This p_2 value was computed by expansion of the probability binomial $(p+q)^n$, where: p = chance of a + difference (1 in 2 or $\frac{1}{2}$); q = chance of a - difference (1 in 2 or $\frac{1}{2}$); and n = number of matched scores. It should be noted that application of the probability binomial to the direction of observed differences between matched scores is not so sensitive a test as the "t" test, since it takes into account only frequencies and not magnitudes.

[19] Cases of 0 difference were placed in the category having the <u>lower</u> number of cases, thereby reducing the amount of difference and resulting in a more conservative estimate of the significance of the difference.

TABLE 2

CONCERNING THE DIFFERENCES BETWEEN MEAN SCORES OF EACH GROUP ON THE LEFT AND RIGHT TURNS, SELECTED INDICES

Index No.	Title	Group	Flt. No.	N*	Mean Score left 720°	Mean Score right 720°	L-R	p_1	No. of diff.	No. of diff.	p_2
	Mean Rank	students	1	7	37.00	41.00	-4.00	.07	--	--	--
			3	9	35.89	41.89	-6.00	.00	--	--	--
		pilots	1	8	41.38	39.50	1.88	.29	--	--	--
			3	10	41.60	41.10	0.50	.37	--	--	--
		instructors	1	5	44.60	47.00	-2.40	.18	--	--	
			3	7	43.29	45.14	-1.85	.21	--	--	--
	Average Slip Magnitude	students	1	9	3.21	8.68	-5.47	.00	--	--	--
			3	9	3.36	8.02	-4.66	.00	--	--	--
		pilots	1	10	3.11	4.76	-1.65	.02	--	--	--
			3	10	2.73	4.41	-1.68	.05	--	--	--
		instructors	1	8	2.83	4.49	-1.66	.06	--	--	--
			3	8	2.71	4.89	-2.18	.01	--	--	--
	Per cent time Slipping	students	1	8	0.54	0.89	-.35	.00	1	7	.03
			3	9	0.52	0.82	-.30	.01	1	8	.02
		pilots	1	10	0.24	0.75	-.51	.01	0	10	.00
			3	10	0.28	0.60	-.32	.00	1	9	.01
		instructors	1	9	0.38	0.65	-.27	.11	2	6	.11
			3	8	0.41	0.60	-.19	.16	2	6	.11
5	Slip Score	students	1	8	1.88	8.04	-6.16	.00	--	--	--
			3	9	2.30	6.95	-4.65	.00	--	--	
		pilots	1	10	1.10	3.91	-2.81	.00	--	--	--
			3	10	0.85	3.12	-2.27	.01	--	--	--
		instructors	1	8	1.69	3.08	-1.39	.17	--	--	--
			3	8	1.59	2.85	-1.26	.15	--	--	--
15	Average Skid Magnitude	students	1	9	3.68	1.68	2.00	.00	--	--	--
			3	9	3.66	1.88	1.78	.02	--	--	--
		pilots	1	10	4.35	2.18	2.17	.00	--	--	--
			3	10	3.98	1.92	2.06	.12	--	--	--
		instructors	1	8	3.53	1.60	1.93	.08	--	--	--
			3	8	4.20	2.05	2.15	.01	--	--	--

*The N's in this and succeeding tables may vary owing to the necessity of discarding scores because of instrumental deficiencies or failure of the subjects to follow instructions (see Appendix B).

TABLE 2 (Cont'd.)

CONCERNING THE DIFFERENCES BETWEEN MEAN SCORES OF EACH GROUP ON THE LEFT AND RIGHT TURNS, SELECTED INDICES

Index No.	Title	Group	Flt. No.	N*	Mean Score left 720°	Mean Score right 720°	L-R	P_1	No. of + diff.	No. of - diff.	P_2
18	Per cent time Skidding	students	1	8	0.24	0.03	0.21	.02	7	1	.03
			3	9	0.23	0.07	0.16	.07	8	1	.02
		pilots	1	10	0.34	0.08	0.26	.00	9	1	.01
			3	10	0.26	0.11	0.15	.05	7	3	.12
		instructors	1	8	0.14	0.13	0.01	.49	4	4	.27
			3	8	0.13	0.08	0.05	.25	4	4	.27
14	Skid Score	students	1	8	0.99	0.14	0.85	.05	--	--	--
			3	9	0.79	0.27	0.52	.04	--	--	--
		pilots	1	10	1.47	0.23	1.24	.00	--	--	--
			3	10	1.00	0.30	0.78	.04	--	--	--
		instructors	1	8	0.66	0.40	0.26	.33	--	--	--
			3	8	0.57	0.19	0.38	.11	--	--	--
24	Average Lateral Imbalance Magnitude	students	1	8	3.48	3.62	-0.14	.02	--	--	--
			3	9	3.77	[illegible]	[illegible]	[illegible]	--	--	--
		pilots	1	10	4.20	4.62	-0.42	.21	--	--	--
			3	10	3.40	4.45	-1.05	.06	--	--	--
		instructors	1	8	3.88	4.21	-0.33	.35	--	--	--
			3	8	3.51	4.31	-0.80	.11	--	--	--
27	Per cent time Lateral Imbalance	students	1	8	0.79	0.92	-0.13	.02	0	8	.00
			3	9	0.74	0.89	-0.15	.06	3	5	.36
		pilots	1	10	0.58	0.84	-0.26	.01	1	9	.01
			3	10	0.54	0.71	-0.17	.05	2	8	.34
		instructors	1	8	0.52	0.78	-0.26	.04	2	6	.11
			3	8	0.53	0.68	-0.15	.19	2	6	.11
23	Lateral Imbalance Score	students	1	8	2.87	8.18	-5.31	.01	--	--	--
			3	9	3.09	7.22	-4.13	.00	--	--	--
		pilots	1	10	2.56	4.14	-1.58	.01	--	--	--
			3	10	1.94	3.42	-1.48	.04	--	--	--
		instructors	1	8	2.35	3.48	-1.13	.15	--	--	--
			3	8	2.16	3.05	-0.89	.21	--	--	--

*The N's in this and succeeding tables may vary owing to the necessity of discarding scores because of instrumental deficiencies or failure of the subjects to follow instructions (see Appendix B).

a. In the case of all indices, the mean scores of the elementary students on the left turn are significantly and consistently different from the mean scores on the right turn with the exception of: Index 1, Mean Bank on Flight 1 (p_1 = .07); Index 18, Per cent Time Skidding on Flight 3 (p_1 = .07 and p_2 = .02); and Index 27, Per cent Time Lateral Imbalance on Flight 3 (p_1 = .06 and p_2 = .16).

b. In the case of all indices except Index 1, Mean Bank, the mean scores of the private pilots on the left turn are also significantly and consistently different from their mean scores on the right turn, with the qualification that the p_2 value for the Index 18, Per cent Time Skidding on Flight 3 is .12. In this comparison, however, one case of 0 difference occurred, which, if grouped with the + instead of the - differences, would reduce the p_2 value to .04.

c. The mean scores of the instructors on the left turn are not significantly and consistently different from their mean scores on the right turn on any of the 10 indices. In the case of two indices (Index 6, Average Slip Magnitude, and Index 15, Average Skid Magnitude), however, the differences in mean scores of the instructors approach significances.

2. <u>Direction of the Differences between Mean Scores</u>. Examination of the "Left-Right" column in Table 2 reveals that, with the exception of Mean Bank, the direction of the difference between the mean scores for the right and left turns on each of the 10 indices is the same for each group. It will also be noted that the direction of these differences reveals consistent trends with respect to maintenance of lateral balance by all groups. In the case of the slip indices (Indices 5, 6, and 9), the mean score for all groups for the right turn is greater than the mean score for the left turn. In the case of the skid indices (Indices 14, 15, and 18) the mean score for all groups for the left turn is greater than the mean score for the right turn. Lastly, in the case of the lateral imbalance indices (Indices 23, 24, and 27), the mean score for all groups for the right turn is greater than the mean score of the left.

3. <u>Nature of the Differences in Left and Right Turn Performance</u>. On the basis of the data presented in Table 2 it is possible to generalize to a certain extent as to the nature of the differences in the performance of right and left turns. First, there seems to be a tendency for the elementary students to bank more steeply on the right turn than on the left. As far as the mean "proper" bank index is concerned, the results are not so clear cut as in the other indices. Considering the index, the reality of this tendency is open to some doubt, not only because the p_1 value of .07 obtained for Flight 1 is below the prescribed level of significance, but also because the private pilots do not show a similar tendency (as they do in the case of the other indices). Also, the extent of error

of measurement in "proper" bank values derived from the R-S load factor indicator, while deemed to be small enough to permit use of the data in an exploratory study such as this, cannot be stated definitely. Only highly significant and consistent difference could be accepted as satisfactory evidence of the tendency.[20]

Apart from the comparisons involving the mean "proper" bank, however, the results clearly indicate that performance of these subjects on the left turn is different in certain respects from performance on the right. The differences are demonstrated to be statistically significant in the case of the less experienced pilots (students and private pilots). In the case of the re-rated instructors (most experienced group) the differences, though not statistically significant, are in the same direction. These facts suggest that the differences result from a tendency (or tendencies) common to all levels of experience but which are presumably minimized by the greater flying experience of the instructors. The nature of the tendency (or tendencies) may be partially inferred from the results. From Table 2, the trends noted in mean scores on the slip and skid indices suggest a tendency to keep the right wing low since the means scores for the right turn on all the slip (right-wing-low) indices is greater than the mean score for the left turn where slipping is left-wing-low. Further, the mean score for the left turn on all the skid(right-wing-low) indices is greater than the mean score for the right turn where skidding is left-wing-low.[21]

Having identified the nature of this tendency, it remains to examine the means whereby it exists and its utility in explaining the outstanding differences between left and right turn performance. The tendency to keep the right wing low, as noted above, is common to all groups of subjects. It is apparent, furthermore, that this tendency may reside either in the structural characteristics of the test airplane or in the subjects themselves. Two possible explanations of this tendency may be set up:[22]

a. The aerodynamic characteristics of the test airplane were such that it tended to fly right-wing-low.

---

[20]Viteles, M. S., and Backstrom, Oscar, Jr. Op. cit. The results obtained, of course, constitute presumptive evidence of such a tendency which might be checked by future research employing a more accurate load factor indicator and a more suitable installation.

[21]It is to be noted that the nature of the tendency is such that right-wing-low slipping is greater than left-wing-low slipping, and right-wing-low skidding is greater than left-wing-low skidding. It does not necessarily follow, however, that skidding on the left turn (right-wing-low) is any greater in amount than slipping on the left turn (left-wing-low).

[22]A full consideration of the possible sources of these differences as considered in the two explanations is presented in Appendix D.

b. When the less experienced pilots apply right aileron, they tend to apply it to excess, and when they apply left aileron, they tend to apply it insufficiently.

Either of these explanations can account for the fact that the less experienced pilots slip more on the right turn than on the left and skid more on the left turn than on the right. They can also account for the fact that the more experienced pilots do not exhibit a significant difference between left and right turn slipping or between left and right turn skidding.[23]

Certain questions arise immediately as to the generality of this right-wing-low tendency. First, would this group of pilots show the same tendency in other airplanes? Obviously, if the right-wing-low tendency is entirely attributable to the aerodynamic peculiarities of the test airplane, it might be entirely absent in others. This experiment was not designed in a manner which permits this question to be answered. However, on the basis of other evidence (see Appendix D) it seems likely that even if the subjects showed this tendency while flying other airplanes, it might not be so marked as in flying the test airplane.

A second question might be, Is the right-wing-low tendency general among all pilots? A general answer to this question is found in the fact that the consistent direction of the mean scores (see Table 2) for all groups would seem to indicate that the tendency is common to all experience levels. In order to investigate this question further, the data were re-examined to see whether the tendency was general among the individual pilots studied. The results of this analysis indicated that (with very few exceptions) the right-wing-low tendency applies not only to groups of pilots, but also to the individual pilot.[24]

---

[23]That the tendency may nevertheless be present is indicated by the fact that their mean scores on the slip items of the right turn are higher (but not significantly) than their mean scores on the left turn. Also, their mean scores on the skid items of the left turn are higher (but not significantly) than their mean skid scores on the right.

[24]The results of the analysis of the individual pilots may be briefly summarized as follows:

a. In the case of the skid score and the average magnitude there were no subjects who had a greater score on the right turn than on the left for both flights, although there were several instances of reversals on one flight. There were therefore no consistent reversals of this tendency. In the case of the proportion of time spent in skidding only 3 out of the 26 subjects showed a consistent reversal of this tendency for both flights. These 3 men were instructors.

b. In the case of the slip score and the proportion of time spent in slipping, only two subjects (2 of the above 3 mentioned instructors) showed consistent reversals of the tendency to keep the right wing low for both flights. In the case of the average magnitude of slip, one of these same instructors and one private pilot showed reversals.

Differences Between Slipping and Skidding. Although the above explanations explain certain of the differences in performance on right and left turns, neither of them can account for the fact that the mean score of each group on lateral imbalance (slipping-skidding) indices is greater for the right turn than the left. In order fully to explain these observations, comparisons (by means of Student's t for matched scores) were made of the slip scores and skid scores of each group to determine whether they slipped or skidded to a significantly different amount on each direction of turn. It should be noted that these scores are composites, involving both the magnitude of the fault, and the time spent in slipping or skidding. The mean scores for each group on each direction of turn and the p values of the differences are presented in Table 3.

TABLE 3

DIFFERENCES BETWEEN MEAN SLIP AND SKID SCORES OF EACH GROUP ON ALL TURNS*

Group	Direction of Turn	Flight No.	N	Mean Slip Score	Mean Skid Score	Slip-Skid	p
students	Left	1	8	1.88	0.99	0.89	.17
		3	9	2.30	0.79	1.51	.06
	Right	1	8	8.04	0.14	7.90	.00
		2	8	5.30	0.49	4.81	.01
		3	9	6.95	0.27	6.68	.00
pilots	Left	1	10	1.10	1.47	-0.37	.20
		3	10	0.85	1.08	-0.23	.31
	Right	1	11	3.92	0.28	3.64	.00
		2	11	3.33	0.22	3.11	.00
		3	11	3.22	0.27	2.95	.00
instructors	Left	1	8	1.69	0.66	1.05	.19
		3	8	1.59	0.57	1.02	.12
	Right	1	8	3.08	0.40	2.68	.01
		2	8	2.68	0.35	2.33	.02
		3	8	2.85	0.19	2.66	.00

*No comparisons are presented for the left turn of Flight 2 on any of the analyses, since the records for this turn were not read. The N's of any analysis in this report may vary owing to the necessity of discarding scores because of instrumental deficiencies or failure of subject to follow instructions (see Appendix B).

Examination of Table 3 reveals that all groups slip significantly more than they skid on the right turn (using the 5% level of significance). In no case does the difference between slip and skid scores on the left turn meet the 5% criterion of significance, although this difference for the elementary students approaches significance (p value = .06) for the left turn on Flight 3. As to the direction of the differences on the turns, it can be seen that the mean slip scores of both the students and the instructors are higher than the mean skid scores on both left turns. The private pilots, however, exhibit a mean skid score higher than the mean slip score on both left turns.

The evidence from Table 3 points to the existence of another tendency which, in conjunction with the tendency to keep the right wing low, can account for all of the facts thus far revealed concerning the nature of the differences in right and left turns. This tendency is the greater proneness to slipping than to skidding. The evidence for this tendency is not, however, completely definitive since the differences between slipping and skidding on the left turn are not significant. It will be recalled, however, that the subjects in this study also display a tendency to keep the right wing low. Skidding on the left turn consists in holding the right wing low. Therefore, if the tendency to slip and the tendency to hold the right wing low exist, they would operate to offset each other on left turns.

Conclusive evidence of proneness to slipping may be obtained by holding constant the variable of the specific wing (whether right or left), i.e., by comparing left-wing-low slipping with left-wing-low skidding. In Table 4 are presented the comparisons of the slip score on the right turn with the skid score on the left, (each fault consisting in keeping the right wing low), and the comparisons of the slip score for the left turn with the skid score of the right (each fault consisting in keeping the left wing low). Comparisons were made by means of Student's t for matched groups for each group on each flight.

TABLE 4

DIFFERENCES BETWEEN MEAN LEFT-WING-LOW AND MEAN RIGHT-WING-LOW SCORES

	Group	Flight No.	N	Mean Slip Score left 720°	Mean Skid Score right 720°	Slip-Skid	p
Left-wing-low Scores	students	1	8	1.88	.14	1.74	.01
		3	9	2.30	.27	2.03	.01
	pilots	1	10	1.10	.23	.87	.05
		3	10	.85	.30	.55	.06
	instructors	1	8	1.69	.40	1.29	.04
		3	8	1.59	.19	1.40	.04
Right-wing-low Scores	students	1	8	8.04	.99	7.05	.00
		3	9	6.95	.79	6.16	.00
	pilots	1	10	3.91	1.47	2.44	.01
		3	10	3.12	1.08	2.04	.02
	instructors	1	8	3.08	.66	2.42	.01
		3	8	2.85	.57	2.28	.00

The results in Table 4 clearly demonstrate the reality of the greater proneness to slipping than to skidding. The mean left-wing-low slip score of each group on each flight is significantly greater than the mean left-wing-low skid score (with the exception of one comparison, p value = .06); and the mean right-wing-low slip score for each group on each flight is significantly greater than the mean right-wing-low skid score.

The Significance of the Right-Wing-Low Tendency and the Proneness to Slipping. All of the observed differences between left and right turn performance with respect to lateral balance and all of the differences in slipping and skidding on each turn may be accounted for in terms of two tendencies: the tendency to keep the right wing low, and the greater proneness to slipping as compared with skidding.

The implications of these two tendencies for aircraft operation may be briefly summarized as follows:

1. On right turns, all groups may be expected to slip more than skid since both of the tendencies operate to induce slipping and neither operates to produce skidding (see Table 3).

2. On left turns, no significant differences may be expected in slipping and skidding since the right-wing-low tendency (operating to induce skidding) will offset the proneness to slipping (see Table 3).

3. More slipping may be expected on the right turns than on the left since, in the case of right turns, slipping is induced by both tendencies, while in the left turn only one of the tendencies operates to produce slipping and this is offset or equalized by the right-wing-low tendency. It might also be expected that there would be a greater difference in right and left turns slipping in the case of the less experienced pilots (see Table 2). Conversely, more skidding would be expected in left turns than in right turns.

4. Since, in left turns, the two tendencies offset one another, lateral imbalance may be expected to be less in left turns than right. Also, it might be expected that the differences would be less in experienced pilots (see Table 2).

5. Even the effect of the instructors' experience in flying is not sufficient to compensate for the effect of the two tendencies in combination (when compared with a situation in which neither tendency is operating) since on right turns the instructors slip more than they skid (see Table 3).

Comparison of the Three Experimental Groups. As in the evaluation of the qualitative method of analyzing R-S Ride Recorder records,[25] the degree of relationship between the quantitative indices and pilot status may be taken as indicative of the validity of the indices as measures of differential pilot

---

[25] Viteles, M. S., and Backstrom, Oscar, Jr. Op. cit., pp. 43-51.

performance. Since the three groups differed with respect to experience (in terms of total flying time) the quantitative indices of the groups might reasonably be expected to differ, with the instructors obtaining the best scores and the students the poorest scores. Whether the scores of the private pilots would be closer to those of the instructors or of the students would depend upon the nature of the learning curve of the elements of flight performance measured by the quantitative indices. If the curve is assumed to have a rapid initial rise and early leveling off, the performance of the private pilots would be closer to that of the instructors. If learning proceeded slowly and the final level attained only after considerable flight experience, the private pilots' performance would be closer to that of the students.

The three groups were compared by testing the significance of the differences between pairs of mean scores through use of Student's t test for unmatched groups.[26] Available for such comparisons were mean scores on each of the 31 indices for right turns on all flights (1, 2, 3) and for the left turns for flights 1 and 3. Tables 5 to 9, inclusive, present the results of these comparisons, including the means for each of the three groups, the differences between means, and the significance of the differences. The direction of the differences is indicated by the appropriate algebraic sign; in each case the second of the pair of groups being compared was subtracted from the first.

---

[26] Whether the difference between two groups will attain statistical significance by this test depends upon the variance of scores within each group as well as the magnitude of the differences between means. (The larger the variance, the greater must be the difference between means in order to attain significance.) In considering the results of the inter-group comparisons presented in the pages following, the reader should bear in mind the fact that as this study was designed, the variance within each group would be expected to be relatively large, because each group was somewhat heterogeneous with respect to flying time and experience, as indicated in the following:

a. The range of total flying time of the elementary students was 15 to 29 hours.

b. The range of total flying time of the private pilots was 35 to 84 hours.

c. The range of total flying time of the instructors was 300 to 4,000 plus hours.

d. Some individuals in each group were relatively unfamiliar with the test airplane, having had only an initial familiarization flight previously, while some were thoroughly familiar with it.

e. The instructors varied widely in their principal types of flying experience.

In one sense, this heterogeneity of the experimental groups is a flaw in the experimental design, since it might have obscured real differences between experience levels that would have been revealed if each group had been more homogeneous; for example, if all the students had had 8-12 hours of flying time, all the private pilots had had 35-45 hours, and all the instructors had had 2000-3000 hours, and if all had had more than an initial familiarization with the test airplane. In another sense, however, it is a conservative feature, since the differences revealed among these heterogeneous groups may be expected to be more apparent among groups more "purely" sampled, and to apply more generally to all samples of "elementary students," "private [illegible]

1. Bank Items (See Table 5)[27]

Index 1: Mean "proper" bank. On the left turns, the means of the three groups fall in the expected order of excellence, the instructors' mean bank most closely approaching the prescribed bank[28] and the students' mean bank being farthest from the prescribed bank. The instructors were significantly superior to the students on both flights and to the pilots on neither flight. The pilots were superior to the students on one of the two flights.

On the three right turns, no instances of significant differences occurred. The mean banks of the students and private pilots were virtually identical. The instructors' score was highest on all flights, however, and superiority over the private pilots approached significance on two of the three flights and over the students on one of the flights.

The absence of significant differences between the scores of the students and the other two groups on the right turn, and their presence on the left turn, may be attributable in part, at least, to the previously demonstrated tendency of the students to bank significantly higher on the right turn than the left, while neither the private pilots nor the instructors showed a significant difference between the mean "proper" bank on the right and left turns. Thus, the students improve their mean bank on the right turn sufficiently to approach the level of proficiency of the instructors and private pilots, although differentiated from the others on the left turn.

Index 2: Fluctuation in "proper" bank. This index revealed no significant differences between groups. The results are consistent, however, in that the instructors showed the least amount of fluctuation on all five flights and the private pilots the greatest amount.

---

[27] It is to be borne in mind that the bank items treated in Table 5 contain certain physical errors of unknown extent. As indicated in Viteles, M. S., and Backstrom, Oscar, Jr., Section B, op. cit., the magnitude of these errors is believed to be small enough to permit treatment of these items in this exploratory study, although the possibility remains that either or both the negative and positive results reported here might be in part due to the influence of these errors.

[28] The prescribed bank of 60° is virtually the upper limit of bank able to be maintained in light airplanes of low horsepower. The test plane used in this study was an Aeronca tandem trainer and it was expected that the mean score on this index of all groups would be considerably lower than the prescribed bank. The mean banks in Table 5 are mostly within the range of 40°-50°.

TABLE 5

DIFFERENCES AMONG MEAN SCORES OF STUDENTS, PILOTS, AND INSTRUCTORS FOR BANK ITEMS

Item No.	Title	Turn and Flight		Groups: Stud. (S)	Pilots (P)	Inst. (I)		Differences: I-S	P-S	I-P
		Left 1	Mean	37.25	41.38	44.60	Diff.	+7.35	+4.13	3.2[illegible]
			N	[illegible]	8	5	p	.01	.12	*
		Left 2	Mean	[illegible]	41.60	43.29	Diff.	+7.40	+5.71	[illegible]
			N	[illegible]	10	7	p	.00	.01	[illegible]
[illegible]	[illegible] Bank	Right 1	Mean	41.00	40.11	47.00	Diff.	+6.00	+ .89	6.89
			N	[illegible]	9	5	p	.09	*	[illegible]
		Right 2	Mean	41.71	40.22	44.50	Diff.	+2.79	+1.49	4.28
			N	7	9	6	p	.19	.30	.0[illegible]
		Right 3	Mean	[illegible]	41.10	45.14	Diff.	+3.25	+ .79	+4.04
			N	9	10	7	p	.19	.41	.1[illegible]
		Left 1	Mean	[illegible]	1.55	1.09	Diff.	-.52	+.04	.56
			N	8	8	5	p	.11	*	.10
		Left 2	Mean	1.60	1.53	1.33	Diff.	-.27	-.07	.20
			N	9	9	7	p	*	*	*
[illegible]	Bank Indication	Right 1	Mean	1.39	1.55	1.25	Diff.	-.14	-.16	.30
			N	7	7	4	p	*	*	*
		Right 2	Mean	1.53	1.79	1.39	Diff.	-.14	-.26	.40
			N	[illegible]	9	6	p	*	*	*
		Right 3	Mean	1.33	1.55	1.14	Diff.	-.19	-.32	-.41
			N	7	10	7	p	*	*	.1[illegible]

*The non-significance of the difference in certain instances was determined by inspection; the exact p value was not derived.

2. Time Measures (see Table 6)

Index 3: Time to attain "proper" bank of 30°. Of all five flights, this index places the groups in the expected order of excellence, although the differences are not consistently significant.[29] However, the superiority of the instructors over the students is significant, or approaches significance, on four of the five flights, and of the private pilots over the students on three of the five flights. On only one flight are the instructors significantly superior to the private pilots.

Index 4: Total Time of Maneuver. On this index the groups fall in the expected order on all five flights, the instructors completing the turn in the shortest average time. The data show that the instructors are most often significantly differentiated from the students, while the differences between private pilots and students and between instructors and private pilots show no consistent significant differentiation.

In view of the variables which enter into the magnitude of this index, little importance per se would seem to attach to these instances of significant differentiation. The trends noted here, however, are of considerable importance in evaluating results on certain other indices: namely, those indices defined as the absolute time spent in a fault of lateral balance (slipping, skidding, lateral imbalance, slipping at or beyond a certain "critical" level etc.) These results suggest that inter-group differences in such items may be in part attributable to inter-group differences in the time spent in the maneuver, and the conclusion that proportions must be employed to reveal true differences in the given fault.

3. Items Dealing with Slipping (see Table 7). Table 7 presents the results in Indices 5 to 13, inclusive, which deal with various aspects of slipping. The results differ markedly depending upon the direction of the turn and will thus be discussed separately.

Left Turn. On the left turn, the private pilots most often rank first on these indices, the instructors most often rank second, and the students, with two exceptions (Indices 11 and 13, Flight 1), rank third. The rank of the students is in accord with expectations, but the ranks of the private pilots and instructors are reversed.

---

29 This lack of consistent significant differentiation may be due, in some part, to the arbitrary selection of 30° as the end point of the entry, to errors in signalling the beginning of the maneuver, and to physical errors in the determination of the first point of attainment of a "proper" bank of 30°.

TABLE 6

DIFFERENCES AMONG MEAN SCORES OF STUDENTS, PILOTS, AND INSTRUCTORS FOR TIME MEASURES

[illegible]	[illegible]	Turn and Flight		Groups Stud. (S)	Pilots (P)	Inst. (I)		Differences I-S	-S	
		Left 1	Mean	27.00	10.[illegible]	6.00	Diff.	-11.00	-6.67	[illegible]
			N	8	6	3	p	.01	.05	
		[illegible]	Mean	[illegible]	10.10	9.00	Diff	-4.33	-3 23	
	[illegible]		N		10	[illegible]	p	.07	10	
		Right 1	Mean	[illegible]	[illegible]	[illegible]	Diff.	[illegible] 43	-4 18	
			N	[illegible]	[illegible]	[illegible]	p	20	14	
		[illegible] 2	Mean	[illegible]	[illegible]	[illegible]	Diff.	[illegible] 31	-1 04	
			N	[illegible]	9	[illegible]	p	09	24	
		Right 3	Mean	[illegible]	[illegible]	[illegible]	Diff.	[illegible] 56	-2.00	
			N	9	9	5	p	01	.09	
		Left 1	Mean	76.13	68.25	66.83	Diff.	-9.30	7 88	
			N	[illegible]	8	6	p	.10	20	
		Left 2	Mean	72.44	64.82	63.57	Diff	-8.87	7.62	
			N	9	11	7	p	.02	.03	
4	Total Time	Right 1	Mean	75.13	70.00	66.17	Diff	-8 96	-5.13	3 [illegible]
			N	8	10	6	p	12	.28	
		Right 2	Mean	87.43	64.91	56.43	Diff.	-11.00	-2.52	8 4[illegible]
			N	7	11	7	p	.03	.30	
		Right 3	Mean	64.56	60.10	54.67	Diff.	-9 89	-4.46	[illegible]
			N	9	10	6	p	.04	.2[illegible]	

Few instances of significant differentiation occur on the left turn. There are no instances of significant differentiation of students and instructors, or of instructors and private pilots. In the case of two indices, however, the time spent in slipping (Index 8) and the per cent time spent in slipping (Index 9), the private pilots are consistently and significantly differentiated from the students, and there are several other isolated instances of significant differentiation of these two groups.

__Right Turn.__ On the right turn, the anticipated ranks of the three groups are obtained almost universally, viz.: instructors, first; private pilots, second; and students, third. Moreover, on the right turn, the instructors are consistently and significantly differentiated from the students in the case of Indices 5 to 13, inclusive. With the exception of Indices 8, 9, and 11, the private pilots are also consistently and significantly differentiated from the students. The private pilots and instructors, however, are not differentiated in any instance.

The results presented in Table 7 may be summarized as follows:

a. On the left turn, the students spend significantly more time, and a significantly greater per cent of time, in slipping than the private pilots. The students and private pilots, however, do not differ significantly on the left turn in the magnitude of slip, in the time and per cent of time spent in slipping beyond the selected "critical" magnitudes, or in the composite slip score which takes into account both the magnitude of slip and the time spent in slipping.

b. On the left turn, the instructors do not differ significantly from either the private pilots or from the students in the case of any of the slip indices.

c. On the right turn, the instructors spend significantly less time, and a significantly smaller per cent of time, in slipping at or beyond the selected "critical" values than the students, and have a mean slip score significantly smaller than the mean slip score of the students.

d. With the exception of Indices 8, 9, and 11, the private pilots are also consistently and significantly better than the students on the right turn with respect to slipping.

e. The instructors and private pilots do not differ significantly with respect to slipping on the right turn, although the mean scores of the instructors on each index for each flight are almost invariably superior to the mean scores of the private pilots.

TABLE 7

DIFFERENCES AMONG MEAN SCORES OF STUDENTS, PILOTS, AND INSTRUCTORS FOR SLIPPING

Index No.	Title	Turn and Flight		Groups: Stud. (S)	Pilots (P)	Inst. (I)		Differences: I-S	P-S	I-P
		Left 1	Mean	1.88	1.10	1.69	Diff.	-.19	-.78	+.59
			N	8	10	8	p	.42	.14	.26
		Left 3	Mean	2.30	.85	1.59	Diff.	-.71	-1.45	+.74
			N	9	10	8	p	.25	.03	.14
5	Slip Score									
		Right 1	Mean	8.04	3.92	3.08	Diff.	-4.96	-4.12	-.84
			N	8	11	8	p	.01	.01	.23
		Right 2	Mean	5.30	3.33	2.68	Diff.	-2.62	-1.97	-.65
			N	8	11	8	p	.04	.08	.28
		Right 3	Mean	6.95	3.22	2.85	Diff.	-4.10	-3.73	-.37
			N	9	11	8	p	.02	.02	.36
		Left 1	Mean	3.21	3.11	2.83	Diff.	-.38	-.10	.28
			N	8	10	8	p	*	*	*
		Left 3	Mean	3.36	2.73	2.71	Diff.	-.65	-.63	-.02
6	Average Slip Magnitude		N	9	10	8	p	*	*	*
		Right 1	Mean	8.68	4.97	4.49	Diff.	-4.19	-3.71	-.48
			N	8	11	8	p	.01	.02	*
		Right 2	Mean	6.32	4.34	3.60	Diff.	-2.72	-1.98	-.74
			N	8	11	8	p	.04	.05	*
		Right 3	Mean	8.02	4.56	4.89	Diff.	-3.13	-3.46	+.33
			N	9	11	8	p	.05	.03	*

*The non-significance of the difference in certain instances was determined by inspection; the exact p value was not derived.

TABLE 7 (Cont'd)

DIFFERENCES AMONG MEAN SCORES OF STUDENTS, PILOTS, AND INSTRUCTORS FOR SLIPPING

Index No.	Title	Turn and Flight		Groups: Stud. (S)	Pilots (P)	Inst. (I)		Differences: I-S	P-S	I-P
7	Maximum Slip Magnitude	Left 1	Mean	8.63	7.60	6.25	Diff.	-2.38	-1.03	-1.35
			N	8	10	8	p	.18	.36	.33
		Left 3	Mean	9.33	7.10	7.25	Diff.	-2.08	-2.23	+ .15
			N	9	10	8	p	.28	.17	.48
		Right 1	Mean	19.25	11.18	10.75	Diff.	-8.50	-8.07	-.43
			N	8	11	8	p	.01	[illegible]	.43
		Right 2	Mean	13.50	10.00	8.50	Diff.	-5.00	-3.50	-1.50
			N	8	11	8	p	.02	.04	.27
		Right 3	Mean	17.78	10.73	10.25	Diff.	-7.53	-7.05	-.48
			N	9	11	8	p	.02	.02	.41
8	Time Slipping	Left 1	Mean	43.13	16.50	25.13	Diff.	-18.00	-26.63	+8.[illegible]
			N	8	10	8	p	.07	.00	[illegible]
		Left 3	Mean	38.67	17.80	24.88	Diff.	-13.79	-20.87	+7.[illegible]
			N	9	10	8	p	.12	.01	.27
		Right 1	Mean	66.25	51.55	42.13	Diff.	-24.12	-14.70	-9.42
			N	8	11	8	p	.00	.05	.15
		Right 2	Mean	51.75	43.18	33.38	Diff.	-18.37	-8.57	-9.80
			N	8	11	8	p	.06	.17	.26
		Right 3	Mean	53.78	36.00	33.88	Diff.	-19.90	-17.78	-2.[illegible]
			N	9	11	8	p	.01	.02	.3[illegible]
9	Per cent Time Slipping	Left 1	Mean	.54	.24	.38	Diff.	-.16	-.30	+.14
			N	8	10	8	p	.15	.01	.14
		Left 3	Mean	.52	.28	.41	Diff.	-.11	-.24	+.13
			N	9	10	8	p	.25	.03	.14
		Right 1	Mean	.89	.73	.65	Diff.	-.24	-.16	-.08
			N	8	11	8	p	.02	.04	.26
		Right 2	Mean	.78	.67	.57	Diff.	-.21	-.11	-.10
			N	8	11	8	p	.10	.20	.26
		Right 3	Mean	.82	.61	.60	Diff.	-.22	-.21	-.01
				9	11	8	p	.02	.03	.50

TABLE 7 (Cont'd.)

DIFFERENCES AMONG MEAN SCORES OF STUDENTS, PILOTS, AND INSTRUCTORS FOR SLIPPING

Index No.	Title	Turn and Flight		Groups: Stud. (S)	Pilots (P)	Inst. (I)		Differences: I-S	P-S	I-P
10.	Time, moderate Slip or greater	Left 1	Mean	7.25	5.10	8.38	Diff	+1.13	-2.15	+3.28
			N	8	10	8	p	.42	.30	.25
		Left 3	Mean	15.00	2.90	6.25	Diff	-8.75	-12.10	+3.35
			N	9	10	8	p	.14	.03	.17
		Right 1	Mean	47.63	24.82	17.00	Diff	-30.63	-22.81	-7.82
			N	8	11	8	p	.00	.01	.18
		Right 2	Mean	34.63	20.91	14.63	Diff	-20.00	-13.72	-6.28
			N	8	11	8	p	.02	.09	.23
		Right 3	Mean	37.56	17.82	14.88	Diff	-22.68	-19.74	-2.94
			N	9	11	8	p	.01	.02	.34
11.	Per cent Time Moderate Slip or greater	Left 1	Mean	.09	.09	.13	Diff	+.04	0	+.04
			N	8	10	8	p	.33	.50	.31
		Left 3	Mean	.20	.05	.10	Diff	-.10	-.15	+.05
			N	9	10	8	p	.17	.04	.18
		Right 1	Mean	.65	.38	.28	Diff	-.37	-.27	-.10
			N	8	11	8	p	.01	.03	.23
		Right 2	Mean	.51	.34	.25	Diff	-.26	-.17	-.09
			N	8	11	8	p	.04	.14	.25
		Right 3	Mean	.56	.31	.29	Diff	-.27	-.25	-.02
			N	9	11	8	p	.02	.03	.44

TABLE 7 (Cont'd.)

DIFFERENCES AMONG MEAN SCORES OF STUDENTS, PILOTS, AND INSTRUCTORS FOR SLIPPING

Index No.	Title	Turn and Flight		Groups: Stud. (S)	Pilots (P)	Inst. (I)		Differences: I-S	P-S	I-P
12.	Time, Large Slips	Left 1	Mean	2.25	1.50	1.75	Diff	-.50	-0.75	+.25
			N	8	10	8	p	*	*	*
		Left 3	Mean	3.00	0.40	1.63	Diff	-1.37	-2.60	+1.23
			N	9	10	8	p	.28	.05	.21
		Right 1	Mean	27.13	5.45	2.75	Diff	-24.38	-21.68	-2.70
			N	8	11	8	p	.01	.01	.22
		Right 2	Mean	14.88	3.55	2.38	Diff	-12.50	-11.33	-1.17
			N	8	11	8	p	.05	.05	.34
		Right 3	Mean	18.89	4.55	2.25	Diff	-16.64	-14.34	-2.30
			N	9	11	8	p	.03	.03	.24
13.	Per cent Time, Large Slips	Left 1	Mean	.03	.03	.08	Diff	0	0	0
			N	8	10	8	p	.50	.50	.50
		Left 3	Mean	.04	.01	.02	Diff	-.02	.03	-.01
			N	9	10	8	p	.25	.06	.34
		Right 1	Mean	.36	.09	.05	Diff	-.31	-.27	-.04
			N	8	11	8	p	.02	.02	.33
		Right 2	Mean	.20	.05	.05	Diff	-.15	-.15	0
			N	8	11	8	p	.08	.05	.50
		Right 3	Mean	.27	.08	.05	Diff	-.22	-.19	-.03
			N	9	11	8	p	.03	.04	.30

*The non-significance of the difference in certain instances was determined by inspection; the exact p value was not derived.

4. <u>Items Dealing with Skidding (see Table 8)</u>. Table 8 presents the results on Indices 14 to 22, inclusive. These indices measure aspects of skidding similar to those of slipping, as presented in Table 7. As in slipping, the results of indices on the left turns differ from those on the right turns.

On the left turn, the instructors most often rank first on these indices, the students most often rank second, and the private pilots most often rank third. On the right turn, the ranks of the mean scores of the three groups occur in somewhat random fashion. The most consistent relationship occurs in the case of Indices 17 and 18, the time spent in skidding and the per cent of time spent in skidding, respectively. On these two indices, the students rank first for all flights, and with the exception of Flight 3, the private pilots rank second and the instructors, third. These results are therefore not in accord with the expected performance of the three groups. On none of the skid indices are any of the three groups consistently and significantly differentiated from any of the others. Isolated instances of significant differentiation occur, but wherever such appear, the differences on the remaining flights are not significant. It may be stated, therefore, that there is little difference among the three experimental groups with respect to the time and the per cent of time spent in skidding, the magnitude of skid, the time and per cent of time spent in skidding at or beyond the selected "critical" values, and the composite skid score, on either left or right turns.

5. <u>Items Dealing with Lateral Imbalance (see Table 9)</u>. Table 9 presents results on Indices 23 to 31, inclusive. These indices are similar in nature to those of slipping and skidding and are essentially a summation of the two types of fault.

As in the case of the slip indices (see Table 7), the results obtained on the right turn for the lateral imbalance indices (Indices 23 to 31, inclusive) differ markedly from the results obtained on the left turn.

On the left turn, the students most often rank third on these indices. The private pilots and instructors each attain first rank with approximately equal frequency. The students are consistently and significantly differentiated from the private pilots only in the case of Indices 26 and 27, the time spent in lateral imbalance, and the per cent of time spent in lateral imbalance, respectively. The students are consistently differentiated from the instructors by only one of these indices, namely, Index 26. There are no instances of significant differentiation of the instructors and private pilots

TABLE 8

DIFFERENCES AMONG MEAN SCORES OF STUDENTS, PILOTS, AND INSTRUCTORS FOR SKIDDING*

Index No.	Title	Turn and Flight		Groups: Stud. (S)	Pilots (P)	Inst. (I)		Differences: I-S	P-S	I-P
14.	Skid Score	Left 1	Mean	.99	1.47	.66	Diff	-.33	+.48	-.81
			N	8	10	8	p	.31	.19	.05
		Left 3	Mean	.79	1.08	.57	Diff	-.22	+.29	-.[illegible]
			N	9	10	8	p	.28	.27	[illegible]
		Right 1	Mean	.14	.28	.40	Diff	+.26	+.14	+.[illegible]
			N	8	11	8	p	.16	.14	[illegible]
		Right 2	Mean	.49	.22	.35	Diff	-.14	-.27	+.1[illegible]
			N	8	11	8	p	.34	.16	.2[illegible]
		Right 3	Mean	.27	.27	.19	Diff	-.08	0	[illegible]
			N	9	11	8	p	.32	.50	[illegible]
15.	Aver. Skid Magnitude	Left 1	Mean	3.68	4.35	3.52	Diff	-0.15	+0.67	[illegible]
			N	8	10	8	p	**	**	**
		Left 3	Mean	3.66	3.98	4.20	Diff	+0.54	+0.32	+0.[illegible]
			N	9	10	8	p	**	**	[illegible]
		Right 1	Mean	1.68	2.33	1.60	Diff	-0.08	+0.65	[illegible]
			N	8	11	8	p	**	**	[illegible]
		Right 2	Mean	3.42	1.91	1.99	Diff	-1.43	-1.51	+0.0[illegible]
			N	8	11	8	p	**	.07	[illegible]
		Right 3	Mean	1.83	1.74	2.05	Diff	+0.17	-0.14	+0.31
			N	9	11	8	p	**	**	**

*Data for Indices 20, 21, and 22 are not included in this table. Comparisons were not made for Index 20 since those made for Index 19 showed no consistent significant differences. Indices 21 and 22 contained too many zero scores in all groups and could not be used for differentiating the experimental groups.

**The non-significance of the difference in certain instances was determined by inspection; the exact p value was not derived.

TABLE 8 (Cont'd.)

DIFFERENCES AMONG MEAN SCORES OF STUDENTS, PILOTS, AND INSTRUCTORS FOR SKIDDING*

[illegible] No.	Title	Turn and Flight		Groups: Stud. (S)	Pilots (P)	Inst. (I)		Differences: I-S	P-S	I-P
[illegible]	[illegible]	Left 1	Mean	[illegible]	12.70	6.88	Diff	-.62	+5.20	-5.8[illegible]
			N	[illegible]	10	8	p	**	.01	.0[illegible]
		Left [illegible]	Mean	[illegible]	[illegible]	7.38	Diff	-1.62	-0.50	-1.[illegible]
			N	[illegible]	[illegible]	8	p	**	**	**
		[illegible]	[illegible]	[illegible]	[illegible]	3.[illegible]	Diff	-0.25	+0.28	-0.53
			[illegible]	[illegible]	[illegible]	8	p	**	**	**
		[illegible]	Mean	[illegible]	[illegible]	3.38	Diff	-2.62	-1.44	+0.78
			N	[illegible]	[illegible]	8	p	.20	.08	**
		[illegible]	Mean	[illegible]	[illegible]	[illegible]	Diff	+0.56	-0.20	-0.36
			N	[illegible]	[illegible]	[illegible]	p		**	**
[illegible]	[illegible]	[illegible]	Mean	[illegible]	[illegible]	[illegible]	Diff	[illegible]	+4.12	-14.12
			N	[illegible]	[illegible]	[illegible]	p	[illegible]	.24	.01
		Left 3	Mean	[illegible]	[illegible]	8.00	Diff	[illegible]	+.54	-8.10
			N	9	[illegible]	8	p	[illegible]	.47	[illegible]
		Right 1	Mean	2.65	5.32	7.00	Diff	+4.37	+3.19	-1.18
			N	8	11	8	p	.08	.06	.34
		Right 2	Mean	5.88	6.45	6.75	Diff	+.87	+.57	+.30
			N	8	11	8	p	.42	.44	.48
		Right 3	Mean	3.89	6.27	4.38	Diff	+.49	+2.38	-1.89
			N	9	11	8	p	.42	.28	.32

*Data for Indices 20, 21, and 22 are not included in this Table. Comparisons were not made for Index 20 since those made for Index 19 showed no consistent significant differences. Indices 21 and 22 contained too many zero scores in all groups and could not be used for differentiating the experimental groups.

**The non-significance of the difference in certain instances was determined by inspection; the exact value was not derived.

TABLE 8 (Cont'd.)

DIFFERENCES AMONG MEAN SCORES OF STUDENTS, PILOTS, AND INSTRUCTORS FOR SKIDDING*

Index No.	Title	Turn and Flight		Groups: Stud. (S)	Pilots (P)	Inst. (I)		Differences: I-S	P-S	I-P
18.	Present Time Skidding	Left 1	Mean	.24	.34	.14	Diff.	-.10	+.10	-.20
			N	8	10	8	p	.20	.15	.03
		Left 2	Mean	.23	.26	.13	Diff.	-.10	+.03	-.13
			N	9	10	8	p	.19	**	.14
		Right 1	Mean	.03	.10	.13	Diff.	+.10	+.07	+.03
			N	8	11	8	p	.06	.04	[illegible]
		Right 2	Mean	.09	.10	.12	Diff.	+.03	+.01	+.02
			N	8	11	8	p	.35	.50	**
		Right 3	Mean	.07	.10	.08	Diff.	+.01	+.03	-.02
			N	9	11	8	p	.41	.32	.35
19.	Time, Moderate Skid or Greater	Left 1	Mean	6.75	6.00	3.63	Diff.	-3.12	-.75	[illegible]
			N	8	10	8	p	**	**	[illegible]
		Left 3	Mean	2.89	4.40	3.38	Diff.	+.49	+1.51	[illegible]
			N	9	10	8	p	**	**	**
		Right 1	Mean	.75	.73	1.25	Diff.	+.50	-.02	[illegible]
			N	8	11	8	p	**	**	**
		Right 2	Mean	2.13	.45	1.50	Diff.	.63	-1.68	[illegible]
			N	8	11	8	p	**	.08	[illegible]
		Right 3	Mean	1.22	.82	.25	Diff.	-.97	-.40	[illegible]
			N	9	11	8	p	.16	**	**

*Data for Indices 20, 21, and 22 are not included in this table. Comparisons were not made for Index 20 since those made for Index 19 showed no consistent significant differences. Indices 21 and 22 contained too many zero scores in all groups and could not be used for differentiating the experimental groups.

**The non-significance of the difference in certain instances was determined by inspection; the exact p value was not derived.

TABLE 9

DIFFERENCES AMONG MEAN SCORES OF STUDENTS, PILOTS, AND INSTRUCTORS FOR LATERAL IMBALANCE

[illegible]	Title	Turn and Flight		Groups: Stud. (S)	Groups: Pilots (P)	Groups: Inst. (I)		Differences: I-S	Differences: P-S	Differences: I-P
		Left 1	Mean	2.87	2.56	2.35	Diff.	-.52	-.31	[illegible]
			N	8	10	8	p	.30	*	*
		Left [illegible]	Mean	[illegible].09	1.94	2.16	Diff.	-.93	-1.15	[illegible]
			N	9	10	8	p	.18	.07	.32
[illegible]	[illegible] Imbalance [illegible]	Right [illegible]	Mean	[illegible].18	4.20	3.48	Diff.	4.70	-3.98	-.72
			N	[illegible]	11	8	p	.01	.01	.24
		[illegible] 2	Mean	[illegible].70	3.51	3.03	Diff.	-[illegible].76	-2.25	-.5[illegible]
			N	8	11	8	p	.02	.04	.3[illegible]
		[illegible]	Mean	[illegible]	3.5[illegible]	3.05	Diff.	-4.17	-3.72	-.4[illegible]
			N	9	11	8	p	.02	.02	.32
		Left 1	Mean	3.[illegible]3	4.20	3.38	Diff.	+.40	+.72	-.32
			N	8	10	8	p	*	*	*
		Left 2	Mean	3.77	3.40	3.51	Diff.	-.26	-.37	+.11
			N	[illegible]	10	8	p	*	*	*
[illegible]	Average Lateral Imbalance Magnitude	Right 1	Mean	6.62	4.76	4.21	Diff.	-4.41	-3.86	[illegible]
			N	8	11	8	p	.01	.01	*
		Right 2	Mean	5.42	4.23	4.26	Diff.	-2.17	-2.20	+.0[illegible]
			N	8	11	8	p	.04	.03	*
		Right 3	Mean	7.51	4.60	4.31	Diff.	-3.50	-3.21	-.2[illegible]
			N	9	11	8	p	.03	.03	*

*The non-significance of the difference in certain instances was determined by inspection; the exact p value was not derived.

TABLE 9 (Cont'd.)

DIFFERENCES AMONG MEAN SCORES OF STUDENTS, PILOTS, AND INSTRUCTORS FOR LATERAL IMBALANCE

Index No.	Title	Turn and Flight		Groups: Stud. (S)	Pilots (P)	Inst. (I)		Differences: I-S	P-S	I-P
25	Maximum Lateral Imbalance Magnitude	Left 1	Mean	10.88	13.60	10.63	Diff.	-.25	+2.72	
			N	8	10	8	p	*	*	
		Left 3	Mean	12.11	11.90	11.13	Diff.	-.98	-.21	
			N	9	10	8	p	*	*	
		Right 1	Mean	19.25	11.18	10.75	Diff.	-8.50	-8.07	
			N	8	11	8	p	.01	.01	
		Right 2	Mean	14.88	10.45	10.50	Diff.	-4.38	-4.33	
			N	5	11	8	p	.01	.02	
		Right 3	Mean	17.78	11.27	10.25	Diff.	-7.53	-6.51	
			N	9	11	8	p	.02	.02	
26	Time, Lateral Imbalance	Left 1	Mean	60.50	38.00	32.50	Diff.	-28.00	-22.50	
			N	8	10	8	p	.00	.00	
		Left 3	Mean	54.22	33.90	32.88	Diff.	-21.34	-20.32	
			N	9	10	8	p	.02	.02	
		Right 1	Mean	68.88	57.36	49.13	Diff.	-19.75	-11.52	
			N	8	11	8	p	.01	.09	
		Right 2	Mean	57.63	49.64	40.12	Diff.	-17.51	-7.99	
			N	8	11	12	p	.02	.12	
		Right 3	Mean	57.67	42.27	38.25	Diff.	-19.42	-15.40	
			N	9	11	8	p	.00	.01	

*The non-significance of the difference in certain instances was determined by inspection; the exact p value was not derived.

TABLE 9 (Cont'd.)

DIFFERENCES AMONG MEAN SCORES OF STUDENTS, PILOTS, AND INSTRUCTORS FOR LATERAL IMBALANCE

				Groups				Differences		
Index No.	Title	Turn and Flight		Stud. (S)	Pilots (P)	Inst. (I)		I-S	P-S	I-P
		Left 1	Mean	.79	.58	.52	Diff.	-.27	-.21	.06
			N	8	10	8	p	.02	.02	[illegible]
		Left 3	Mean	.74	.54	.53	Diff.	-.21	-.21	.01
			N	9	10	8	p	.08	.05	.50
27	Per cent Time, Lateral Imbalance	Right 1	Mean	.92	.83	.78	Diff.	-.14	-.09	-.05
			N	8	11	8	p	.03	.12	.28
		Right 2	Mean	.87	.77	.69	Diff.	-.18	-.10	-.08
			N	8	11	8	p	.04	.12	.21
		Right 3	Mean	.89	.71	.68	Diff.	-.21	-.18	-.03
			N	9	11	8	p	.01	.01	.36
		Left 1	Mean	14.00	11.10	12.00	Diff.	-2.00	-2.90	.90
			N	8	10	8	p	.38	.28	*
		Left 3	Mean	17.89	7.30	9.63	Diff.	-8.26	-10.59	+2.33
			N	9	10	8	p	.15	.05	.28
28	Time, Moderate Imbalance or Greater	Right 1	Mean	48.37	25.64	18.13	Diff.	-3.24	-22.73	-7.51
			N	8	11	8	p	.00	.01	.18
		Right 2	Mean	36.75	21.36	16.13	Diff.	-20.62	-15.39	-5.33
			N	8	11	8	p	.01	.06	.26
		Right 3	Mean	38.89	18.64	15.13	Diff.	-23.76	-20.25	-3.51
			N	9	11	8	p	.01	.01	.31

*The non-significance of the difference in certain instances was determined by inspection; the exact p value was not derived.

TABLE 9 (Cont'd.)

DIFFERENCES AMONG MEAN SCORES OF STUDENTS, PILOTS, AND INSTRUCTORS FOR LATERAL IMBALANCE

Index No.	Title	Turn and Flight		Groups: Stud. (S)	Pilots (P)	Inst. (I)		Differences: I-S	P-S	[illegible]
29	Per cent Time, Moderate Lateral Imbalance or greater	Left 1	Mean	.20	.18	.20	Diff.	0	-.02	-.02
			N	8	10	8	p	.50	[illegible]	[illegible]
		Left 3	Mean	.24	.12	.15	Diff.	-.09	-.12	[illegible]
			N	9	10	8	p	.19	.08	
		Right 1	Mean	.65	.40	.31	Diff.	-.34	-.25	[illegible]
			N	8	11	8	p	.01	.04	[illegible]
		Right 2	Mean	.55	.35	.28	Diff.	-.27	-.20	[illegible]
			N	8	11	8	p	.02	.08	[illegible]
		Right 3	Mean	.59	.32	.29	Diff.	-.30	-.27	[illegible]
			N	9	11	8	p	.01	.02	
30	Time, Large Lateral Imbalance	Left 1	Mean	3.38	4.10	2.75	Diff.*	-.63	[illegible]	[illegible]
			N	8	10	8	p	.40	[illegible]	[illegible]
		Left 2	Mean	4.00	1.90	2.38	Diff.	-1.62	-2.10	[illegible]
			N	9	10	8	p	.25	.12	[illegible]
			Mean							
		Right 1	Mean	27.38	5.45	3.00	Diff.	-24.38	-21.93	[illegible]
			N	8	11	8	p	.01	.01	[illegible]
		Right 2	Mean	15.63	3.55	2.50	Diff	-13.13	-12.08	[illegible]
			N	8	11	8	p	.04	.04	[illegible]
		Right 3	Mean	18.89	4.73	2.25	Diff.	-16.64	-14.16	[illegible]
			N	9	11	8	p	.03	.03	[illegible]

*The non-singificance of the difference in certain instances was determined by inspection; the exact p value was not derived.

TABLE 9 (Cont'd.)

DIFFERENCES AMONG MEAN SCORES OF STUDENTS, PILOTS, AND INSTRUCTORS FOR LATERAL IMBALANCE

Index No.	Title	Turn and Flight		Groups: Stud. (S)	Pilots (P)	Inst. (I)		Differences: I-S	P-S	[illegible]
	Per cent Time, Large Lateral Imbalance	Left 1	Mean	.05	.07	.05	Diff.	0	-.02	[illegible]
			N	8	10	8	p	.50	.30	[illegible]
[illegible]		Left 3	Mean	.05	.03	.04	Diff.	-.01	-.02	[illegible]
			N	9	10	8	p	*	.20	*
		Right 1	Mean	.37	.09	.06	Diff.	-.31	-.28	[illegible]
			N	8	11	8	p	.02	.01	*
		Right 2	Mean	.22	.05	.05	Diff.	-.17	-.17	[illegible]
			N	8	11	8	p	.06	.04	[illegible]
		Right 3	Mean	.27	.08	.05	Diff.	-.22	-.19	[illegible]
			N	9	11	8	p	.05	.04	[illegible]

*The non-significance of the difference in certain instances was determined by inspection; the exact [illegible] was not derived.

On the right turn, the anticipated ranks of the three groups are obtained almost universally, viz.: instructors, first; private pilots, second; and students, third.

On the right turn, the students and instructors are consistently and significantly differentiated in the case of all indices. With the exception of indices 26 and 27, the time spent in lateral imbalance and the per cent of time spent in lateral imbalance, respectively, the private pilots are also consistently and significantly differentiated from the students by these indices. As in the left turn, there are no instances of significant differences between instructors and pilots.

Over-all Trends in Inter-Group Differences. Table 10 provides a summarization of the inter-group comparisons presented in Tables 5 to 9, inclusive. It is based on a tabulation of the frequency of instances of superiority of one group over another. On the left turn, for example, the instructors were significantly superior (p value of .05 or less) to the students in 7 of the total of 56 comparisons between these two groups. The total of 56 t tests includes comparisons on 28 indices (t tests were not made on indices 20, 21, and 22) on each of two flights. In a like manner, the total of 84 comparisons on the right turns (28 indices on three flights) were tabulated as to direction and significance of the differences between means.

Inspection of Table 10 reveals the following:

1. Instructors vs. Students.

   a. Of the 56 comparisons of left turns the instructors were superior in 48 instances, of which 12 were significant or approached significance. The students were superior in 5 instances, none significantly.

   b. Of the 84 comparisons of right turns the instructors were superior in 75 instances, of which 59 were significant or approached significance. The students were superior in 9 instances, 2 instances of which approached significance.

   c. Of the total of 140 comparisons, the instructors were significantly superior (p of .05 or less) in 60 instances, while the students were significantly superior in no instance.

2. Pilots vs. Students.

   a. Of the 56 left turn comparisons, the pilots were superior to the students in 39 instances, of which 20 were significant or approached significance. The students were superior in 15 instances; in no case, however, did the difference approach significance.

TABLE 10

INTER-GROUP COMPARISONS FOR LEFT AND RIGHT TURNS

		Left Turn	Right Turn	Total
Instructors vs. Students				
Instructors Superior	Significant	7	53	60
	Approaches significance	5	6	11
	Non-significant	36	16	52
	Equal	3	-	3
Students Superior	Non-significant	5	7	12
	Approaches significance	-	2	2
	Significance	-	-	-
	TOTAL	56	84	140
Instructors vs. Pilots				
Instructors Superior	Significant	3	2	5
	Approaches significance	2	3	5
	Non-significant	27	61	88
	Equal	1	2	3
Pilots Superior	Non-significant	23	16	39
	Approaches significance	-	-	-
	Significant	-	-	-
	TOTAL	56	84	140
Pilots vs. Students				
Pilots Superior	Significant	16	43	59
	Approaches significance	4	9	13
	Non-significant	19	16	35
	Equal	2	1	3
Students Superior	Non-significant	15	13	28
	Approaches significance	-	1	1
	Significant	-	1	1
	TOTAL	56	84	140

b. Of the 84 right turn comparisons, the pilots were superior in 68 instances, 52 of which were significant or approached significance. The students were superior in 15 instances, 13 of which were not significant.

c. Of the total of 140 comparisons, the **pilots were significantly superior (p value of .05 or less) in 59 instances** while the students were significantly superior in only 1 instance.

3. Instructors vs. Pilots.

a. Of the 56 left turn comparisons, the instructors were superior to the pilots in 32 instances, of which only 5, however, were significant or approached significance. The pilots were superior in 23 instances but none approached significance.

b. Of the 84 right turn comparisons, the instructors were superior in 66 instances, of which 5 were significant or approached significance. The pilots were superior in 16 instances, but none approached significance.

c. Of the total of 140 comparisons, the instructors were significantly superior (p value of .05 or less) in only 5 instances; the pilots were significantly superior in no instance.

The over-all trends revealed by this summary tabulation are in accord with the expectation that, if the indices were measures of differential flight performance, the instructor group would obtain the best scores and the students, the poorest scores. In addition, the summary tabulation shows that the private pilots were much more frequently differentiated from the students than from the instructors. In fact, the results show only slight superiority of the instructors over the private pilots.

It may, therefore, be inferred that learning curves of the aspects of performance measured by these indices would show a rapid initial rise and early leveling off. This might be considered as presumptive evidence that the standards of flight proficiency required by the CAA for the private pilot license and the 35-hour training program set up for civilian pilot training are adequate and perhaps even at too high a level. Obviously, and apart from the fact that these data are artifacts of the particular test plane used and may not be applicable to other planes, this evidence is not definitive. It is known neither to what extent proficiency in the aspects of performance measured by these indices is representative of over-all proficiency in executing power turns, nor to what extent proficiency in executing power turns is representative of over-all skill in executing the maneuvers in the CPT course. The evidence, however, is suggestive.

In regard to the instrumentation of this project, the following factors also limit the generality of conclusions to be drawn:

1. As stated previously, the R-S Ride Recorder records gave an indication of only a few aspects of performance. It is possible that the instructors and private pilots differ materially and significantly in other aspects of performance than bank and lateral balance, e.g., maintenance of proper airspeed, correct longitudinal attitude, holding a constant altitude, etc., which cannot be determined from the R-S Ride Recorder.

2. The slow paper speed of 1¼ inches per minute suppressed much detail which may have been a means of discriminating the private pilots and instructors.

As to other statistical procedures, it is possible that the differences between the private pilots and the instructors are of such an order that any one aspect of performance alone will fail to discriminate the two groups, and a "global" use of quantitative indices would be necessary to reveal the differences.[30] Such a "global" approach might, for example, involve the combination of indices by appropriate weighting procedures in order to arrive at over-all scores of proficiency. Weights for the given indices might be arbitrarily assigned in accordance with the judgment of expert pilots as to their relative importance; or might be statistically established using the license status of the subjects as an external criterion.

It was felt, however, that such treatment was beyond the scope of this exploratory study and should await a more ambitious experiment involving both better instrumentation and larger and more appropriately-constituted experimental groups.

Effect of Intra-Group Trends Upon Inter-Group Differences. It has been noted above that inter-group differences in slipping and lateral imbalance differed markedly from left turn to right turn; in particular, the differences among groups were more pronounced on the right turns than on the left turns. It will also be recalled that certain intra-group differences appeared between performance on the left turn and the right turn, as follows: each group had a greater proneness to slipping than to skidding (see Table 4); the less experienced groups, i.e., students and private pilots, had a statistically confirmed tendency to keep the right wing low (see Table 2); the instructors also manifested this right-wing-low tendency in that their right-wing-low slipping and skidding scores were consistently higher than their left-wing-low slipping and skidding scores, although the differences were not statistically significant (see Table 2).

It might be profitable, therefore, to consider the extent to which the differences between left turn and right turn in these inter-group comparisons may be explained in terms of the observed intra-group.

1. Right Turn: Slipping (Indices 5 to 12). In a right turn both the greater proneness to slipping and to skidding and the right-wing-low tendency combine to induce slipping. This combination of both tendencies can be resisted only by the skill of the pilot in compensation, which is presumably a function of experience. It might, therefore, be expected that the three groups (instructors, private pilots, and students) would be consistently and significantly differentiated. As Table 7 shows, this differentiation was obtained in the results.

---

[30] This remark applies only to elementary maneuvers, on at least some of which the private pilots apparently may attain or nearly attain a final plateau of proficiency within the allotted time of the CPT primary course. It would seem likely that private pilots and instructors might be differentiated by indices measuring single aspects of the performance of advanced acrobatic maneuvers.

2. Right Turn: Skidding (Indices 14 to 22). In right turns both tendencies mentioned above would operate to prevent skidding and, therefore, reduce differences among groups. In addition, the students, having spent a greater proportion of the maneuver time in slipping, would have the least opportunity to skid. In contrast, the instructors, having spent a smaller proportion of the time in slipping, would have the greatest opportunity for skidding. It might further be expected that when skidding does occur the instructors would exhibit the smallest magnitude of skid and the students, the largest.

The results in Table 8, in general, are in accord with the expected effect of these two tendencies since none of the three groups is consistently and significantly differentiated from either of the other two. In addition, for Indices 17 and 18, which are directly affected by the time spent in skidding and the percentage of time spent in skidding, the students exhibit the best scores and the instructors the poorest, although the differences are not significant.

3. Right Turn: Lateral Imbalance Items (Indices 23 to 31). Since on right turns the amount of slipping of each group greatly exceeded the amount of skidding, the lateral imbalance items for all groups are composed chiefly of slipping. The results on the lateral imbalance items (see Table 9), therefore, virtually duplicate the results on the slip items.

4. Left Turn: Slipping (Indices 5 to 13). On left turns the two tendencies operate in an antagonistic manner thereby reducing the frequency in the amount of slipping in left turns. Differences among groups might, therefore, be expected to be small since the differential effects of experience are minimized by the "help" given to less experienced groups resulting from the fact that the two tendencies offset each other.

As shown in Table 7, on most of the slip indices in the left turn the students benefit from the opposition of the right-wing-low tendency and the proneness to slip to an extent sufficient to bring their scores close to the scores of the instructors and private pilots. Although the instructors tend to obtain the best scores, the differences among the groups are in general not significant.

It cannot be assumed, of course, that these two tendencies, although present simultaneously, would actually balance each other so that the pilot would neither slip nor skid. The greatest benefit to the inexperienced pilot, unable to resist each tendency successfully, would be in the reduction of the magnitude rather than the time of the slip. This may partially explain the fact that the private pilots were significantly differentiated from the students in Indices 8 and 9, both of which deal with the time factor. Additional evidence for this supposition is found in Table 2 which shows that the students' scores on average magnitude of slip (Index 6) were 8.68 for the right turn and 3.21 for the left turn for Flight 1, a reduction of 63 per cent, whereas the reduction from right turn to left turn in Index 8 was from .89 to .54, or only 39 per cent.

5. <u>Left Turns: Skidding (Indices 14 to 22)</u>. As in slipping, the two tendencies would also operate to reduce skidding in the left turns. As shown in Table 8, none of the three groups is consistently and significantly differentiated from either of the other two on any of the skidding indices, although the instructors most often attain the best scores.

6. <u>Left Turn: Lateral Imbalance (Indices 23 to 31)</u>. Since the lateral imbalance indices take account of both slipping and skidding the effect of the two opposing indices would again be to reduce group differences and result in a lack of significant differentiation among the groups on these indices. As shown in Table 9, the students are consistently and significantly differentiated from both the instructors and the private pilots only in the case of Index 26, time spent in lateral imbalance, and from the private pilots only in the case of Index 27, the percentage of time spent in lateral imbalance.

In general, the differences between the right turn and left turn results are in accord with expectations based upon the effect of these two tendencies and tend to strengthen conclusions as to the value of the quantitative indices as valid measures of pilot proficiency.

<u>Cutting Scores</u>. The fact that two groups, differing in amount of experience, differ significantly in mean scores on a certain index does not necessarily indicate that scores on the index would classify individual pilots in one or the other of the two experience levels on the basis of their individual scores on the particular index. A statistically significant difference in mean scores may have resulted from a few extreme scores within each group, and a large proportion of one group may have scores differing very little from the scores of a large proportion of the other group.

For determining the value of quantitative indices in classifying pilots in terms of experience or proficiency levels, the most practical procedure is through the determination of cutting scores. Although cutting scores obtained in this study are not immediately applicable in the field, because based on small samples of subjects and on the results of only one plane, a preliminary investigation was made to determine the practicability of using the quantitative indices for classifying purposes.

Lateral imbalance items were selected because they are the most comprehensive of the indices pertaining to the maintenance of lateral balance.

Moreover, two of them, Indices 26 and 27, discriminate among the groups on both left and right turns. Accordingly, distribution of scores were plotted for four lateral imbalance indices, namely, Lateral Imbalance Score (Index 23), Time Spent in Lateral Imbalance (Index 26), Percentage of Time Spent in Lateral Imbalance (Index 27), and Time beyond critical level of 10 units for each turn in each group (Index 30).

In most distributions there are usually several points at which cutting scores may be set. Which point is selected will depend upon the practical situation.[31] For example, it is frequently possible on a given distribution to set a score which leads to the acceptance of only those who rank highest on the criterion variable. This score may, nevertheless, be undesirable if the number of such individuals is less than the number required by the practical situation of filling factory jobs, obtaining military pilots, etc. In such a case, a lower cutting score would be required which would lead to the acceptance of some fair and even some poor prospects. Accordingly, several possible cutting scores were selected for each index on the basis of simple inspection.[32]

Table 11 shows the number of cases accepted or rejected in each group by several possible cutting scores on each index. The criteria for acceptance or rejection were as follows:

1. In the case of left turn, an individual was considered to be accepted by the cutting score if his score on both Flight 1 and Flight 3 fell below the cutting score.[33]

2. In the case of right turn an individual was considered to be accepted by the cutting score if his scores on at least two of the three flights fell below the cutting score.

Examination of Table 11 reveals that, in general, satisfactory cutting scores for the right turn were obtained on all four of the indices. Satis-

---

[31]This problem has been discussed in detail in: Johnson, H. M. <u>On the actual and potential value of biographical information as a means of predicting success in aeronautical training</u>. Washington, D. C.: CAA Airman Development Division, Report No. 32, August 1944.

[32]For the purposes of the present study it did not seem desirable to use highly refined statistical techniques for setting cutting scores. The general problem of cutting scores and a method for the selection of the most efficient cutting score are discussed in: Franzen, Raymond. <u>A method for selecting combinations of tests and determining their best "cut-off points" to yield a dichotomy most like a categorical criterion</u>. Washington, D. C.: CAA Division of Research, Report No. 12, March 1943.

[33]Since these indices relate to "faults," a low score represents superior performance.

[illegible] for the left turn were [illegible] significant [illegible], namely, Indices 26 and 27, the same two which [illegible] significant differences among group means in previous comparisons. On Index 26, for example, a cutting score of 40 rejected only one of the instructors but all eight of the students, and a cutting score of 50 rejected one of the instructors and 7 of the 8 students. When the cutting score is raised to 60 it rejects only two of the students and none of the other groups. Although the cutting score of 70 rejects only one student, if acceptance is based upon being above the cutting score [illegible] both turns the score accepts all of instructors and private pilots [illegible] only four of the eight students.

Similar inspection of the other indices shows a cutting score of 60 on Index 27 to reject all the students while rejecting half or less of the private pilots and instructors; "lowering" the cutting score to 75 would accept a group including all of the instructors, all but two of the private pilots, but only two of the students. The results show Index 30 to be of little value in classifying individuals and Index 23 to be only slightly more discriminating.

In spite of the generally satisfactory performance of the cutting scores noted above, in many instances a fairly large proportion of several of the experimental groups is accepted by a given score on turns in one direction, but not on turns in the other. This is true even in the case of the time and the percentage of time spent in lateral imbalance, which differentiate the experimental groups on turns of both directions. For example, referring to Table 11, it may be seen that in the case of the percentage of time spent in lateral imbalance (Index 27):

1. The cutting score of 30% accepts on the left turn 4 individuals not accepted on the right turn.
2. The cutting score of 60% accepts on the left turn 6 individuals not accepted on the right turn, and accepts on the right turn 2 individuals not accepted on the left turn.
3. The cutting score of 75% accepts on the left turn 8 individuals not accepted on the right turn, and accepts on the right turn 4 individuals not accepted on the left turn.
4. The cutting score of 80% accepts on the left turn 8 individuals not accepted on the right turn, and accepts on the right turn 4 individuals not accepted on the left turn.

This situation is in part attributable to the intra-group differences between the left and right turns since on right turns both the students and private pilots have significantly higher scores for lateral imbalance than they do on left turns. [illegible] It would not be expected that the same items [illegible]

---

[3] [illegible]

[illegible]

CUTTING SCORES ON SELECTED INDICES

Index No.	Title	Cutting Score	Group	N	Accepts: Both Turns	Accepts: Left Turn Only	Accepts: Right Turn Only	Rejects on Both Turns
26	Time Spent in Lateral Imbalance	40	Instruc.	8	2	3	2	1
			Pilots	9	1	4	1	3
			Students	8	0	0	0	8
		50	Instruc.	8	2	3	2	1
			Pilots	9	1	5	1	2
			Students	8	0	0	1	7
		60	Instruc.	8	5	1	2	0
			Pilots	9	7	2	0	0
			Students	8	1	3	2	2
		70	Instruc.	8	8	0	0	0
			Pilots	9	8	1	0	0
			Students	8	4	2	1	1
27	Percentage of Time Spent in Lateral Imbalance	50	Instruc.	8	1	3	0	4
			Pilots	9	0	1	0	8
			Students	8	0	0	0	8
		60	Instruc.	8	1	3	1	3
			Pilots	9	1	3	1	4
			Students	8	0	0	0	8
		75	Instruc.	8	1	5	2	0
			Pilots	9	3	3	1	2
			Students	8	1	0	1	6
		80	Instruc.	8	2	4	2	0
			Pilots	9	4	3	1	1
			Students	8	1	1	1	5
30	Time Beyond Critical Level	10	Instruc.	8	7	0	1	0
			Pilots	9	7	1	1	0
			Students	8	2	3	1	2
		15	Instruc.	8	8	0	0	0
			Pilots	9	8	1	0	0
			Students	8	3	5	0	0

TABLE 11

CUTTING SCORES ON SELECTED INDICES

Index No.	Title	Cutting Score	Group	N	Accepts: Both Turns	Accepts: Left Turn Only	Accepts: Right Turn Only	Rejects on Both Turns
			Instruc.	8	2	2	2	2
		2.6	Pilots	9	4	1	1	3
			Students	8	0	3	0	5
			Instruc.	8	2	2	2	2
		3.0	Pilots	9	4	2	1	2
			Students	8	1	3	0	4
	Lateral		Instruc.	8	5	2	1	0
23	Imbalance	4.6	Pilots	9	5	2	0	2
	Score		Students	8	2	2	0	4
			Instruc.	8	6	1	1	0
		5.0	Pilots	9	6	2	0	1
			Students	8	2	3	0	3
			Instruc.	8	8	0	0	0
		7.0	Pilots	9	8	1	0	0
			Students	8	4	4	0	0

cutting score would accept and reject the same individuals on the left and right turn.

In addition, examination of the actual distributions revealed that certain individuals obtained high scores on right turns and low scores on left turns, or vice versa; in other words, the relationship between scores on the individual maneuvers was not very high. Several interpretations of these discrepancies are possible:

1. In the present comparisons, the absence of marked relationship between left and right turn performance may be attributable to the differential effect of the previously noted intra-group trends on the three groups of subjects on left and right turns.

2. The absence of marked relationship might also be attributable to the fact that each index measures only one aspect of the performance. It is possible that the total performances on left and right turns, respectively, are more highly related than the particular aspects measured by these individual indices.

3. On the basis of comparisons presented in the following section it is shown that indices derived from single performances of a maneuver are not adequate for a consistent appraisal of skill in the

day-to-day execution of the maneuver, because of pilot variability from flight to flight. The absence of marked relationship between scores on left and right turns may be one aspect of a general instability of indices such as those devised in this study, each referring to small segments and brief periods of performance in piloting an airplane.

The results do show that it is possible to classify, with respect to experience, pilots performing the same maneuver under standard conditions, through the use of quantitative indices such as those employed in this study. The results presented in Table 11 indicate that for one maneuver, cutting scores or norms may be obtained on indices derived from graphic records which will satisfactorily "place" unselected individuals for that maneuver. The results do not furnish evidence as to the possibility of combining quantitative indices with a view to "placing" pilots with respect to total or global performance. To arrive at more general quantitative indices of pilot performance would involve the analysis and combination of such indices for a number of maneuvers by appropriate weighting procedures and the discovery of those indices which are most highly related with over-all proficiency as a pilot in successive groups of subjects.

<u>Intercorrelations Among Scores on Selected Indices for Successive Flights</u>. As indicated above, indices derived from single performances of a maneuver were not adequate for a consistent appraisal of skill in executing that maneuver because of pilot variability from flight to flight. Additional evidence on variability in performance was obtained by correlating the scores of the subjects on five selected indices for the left turn of the first flight with their scores on the same indices for the left turn of the third flight. In addition, their scores on these same indices for the right turns of Flights 1, 2, and 3 were intercorrelated.

The indices selected for these intercorrelations were:

1. The Slip Score (Index 5), Skid Score (Index 14), and Lateral Imbalance Score (Index 25). As stated earlier, these indices are composite indices each taking into account both magnitude of the particular fault in maintaining lateral balance and the time spent in the fault. Investigation of their successive-flight reliability would therefore indicate the reliability of the total performance of the subjects with respect to lateral balance. Moreover, since these indices are averages, higher intercorrelations would be expected than in the case of single-variable indices; hence, if these indices did not show high successive flight reliability, it might reasonably be concluded that the simpler measures would also not show high successive-flight reliability.

2. The Time Spent in Lateral Imbalance (Index 26) and the Time Spent in Lateral Imbalance at or beyond the "critical" level of 10 units (Index 30). It was thought that intercorrelations of the successive-flight scores on these indices would be of particular interest because of their employment in the investigation of cutting scores.

An inspection of these intercorrelations, presented in Table 12, reveals that:

1. With the exception of the skid-score intercorrelations, significant positive correlation is present in all successive-flight comparisons, since the probability of obtaining the given r through the chance fluctuations of random sampling, if the true r were 0, is lower than .05 in each case.

2. None of the indices, however, can be judged to have a high successive-flight reliability, since the highest intercorrelation of scores on an index for the left turn is +.70, obtained in the case of the slip score. Although the scores on several indices for the right turns of Flights 1 and 2, and 1 and 3, are highly correlated (of the order of +.80), the scores for the right turns of Flights 2 and 3 are not highly correlated in the case of any index.

The degree of variability from flight to flight exhibited by the pilots on the indices under investigation has certain important implications for the employment of the work-sample technique (as represented by standard flights) in the measurement of pilot proficiency. Although the number of cases is small, the following tentative conclusions seem to be justified from the results presented in Table 12 cited above:

1. Although there are wide differences in the consistency of various aspects of performance, the orders of several of the coefficients are sufficiently high to suggest that certain aspects of performance during a single flight give a fairly consistent index of pilot proficiency applying from flight to flight.[35]

2. From an inspection of the data there seems reason to believe that further examination of such quantitative indices under improved experimental conditions may well lead to the identification of those aspects of performance which are particularly acceptable in terms of successive-flight reliability.

3. In the light of general experimentation in this field, it seems likely that such research should be concerned not with single indices, each measuring a limited aspect of performance, but with the combination of indices by appropriate weighting in order to obtain a score representative of at least an entire maneuver. This point of view is somewhat negated by the findings included

---

[35] Subsequent to this study of graphic records, an analogous study has been made of pilot variability from flight to flight as revealed by photographic records. Intercorrelations on such items of performance as average airspeed, average bank, altitude variation, etc., are presented in: Wapner, S., Festinger, L., & Odbert, H. S. Consistency of student pilot performance as observed in photographic records. (A final report to be published in the CAA Technical Series.)

SUCCESSIVE-FLIGHT [illegible] INDICES

Index No.	Title	Turn	Flights	[illegible]	r	p value
		Left	1,3	25	+.70	<.01
6	Slip score		1,2	27	+.84	<.01
		Right	1,3	27	+.81	<.01
			2,3	27	+.57	<.01
		Left	1,3	25	+.32	>.05, <.10
14	Skid score		1,2	27	+.20	>.15, <.20
		Right	1,3	27	+.09	>.30, <.35
			2,3	27	+.20	>.15, <.20
		Left	1,3	25	+.59	<.01
23	Lateral Imbalance score		1,2	27	+.84	<.01
		Right	1,3	27	+.83	<.01
			2,3	27	+.63	<.01
		Left	1,3	25	+.65	<.01
26	Time Lateral Imbalance		1,2	27	+.61	<.01
		Right	1,3	27	+.68	<.01
			2,3	27	+.69	<.01
		Left	1,3	25	+.38	>.02 <.05
30	Time, Large Lateral Imbalance		1,2	27	+.74	<.01
		Right	1,3	27	+.80	<.01
			2,3	27	+.44	>.01 <.02

in Part I of this report which failed to reveal a high order of reliability between qualitative global ratings of maneuvers in successive flights.[36] However, the higher order of reliability found to be characteristic of quantitative measurements as contrasted with qualitative judgments should tend to contribute towards the consistency of a composite index.

4. The possibility of combining scores on different maneuvers to arrive at a single score for an entire flight should also receive consideration in further research. In general, this problem of arriving at a completely acceptable and reliable index of flight performance is of critical importance with respect to the use of single flights such as are employed in the flight inspection program of the CPT in assessing pilot proficiency.

---

[36] See Viteles, M. S., and Backstrom, Oscar, Jr. *Op. cit.*

APPENDIX A

ACCURACY OF MEASUREMENT

ACCURACY OF MEASUREMENT

Further details of the measuring process.

1. Readers employed. Three persons served as readers and recorders in the quantitative measuring [illegible], only two of these three working at a given time. [illegible] served alternately as reader and recorder. The reader [illegible] read the whole of one turn and then became recorder for the next turn.

   The time required (including the handling of the record, insertion into the reflectoscope, and adjusting the screen) for reading each turn varied from about 35 minutes to about an hour and twenty minutes, the average being about 45 - 50 minutes. In the case of unusually long turns, the reader and recorder sometimes exchanged places if the reader became particularly fatigued.

2. Reading the load factor trace. Since the load factor trace contained a superposed complex of vibration traces having the form of a simple sine curve, the reading of load factor at any point was made at the mid-point of this superposed complex of vibration traces.[37] This feature of the records made for some difficulty in reading, since the reader had to determine two points (the top and the bottom of the vibrations trace) and obtain the mid-point between these two to get the reading of load factor. Accuracy was undoubtedly lost because of this feature of the records, since the measuring process is obviously a rather complex and unsatisfactory means of making readings

Further precautions taken to insure accuracy of the readings. One of the three readers, the junior writer, in establishing the measuring technique, had become experienced in the process of measurement. The other two readers[38] made practice readings in his presence until in his judgment they had learned the measuring process. These practice measurements were checked with re-measurements made by the more experienced reader.

Check on the accuracy of the measurements.

1. No formal check on the accuracy of the quantitative measurements was made. The accuracy of the measurements in general depended on so many variables, such as clarity of the record, clarity of the projected image, the particular reader, the practice of the reader, and fatigue of the reader, that it was felt that a single formal check would not be representative of the entire course of the readings

---

[37]See Viteles, M. S., and Backstrom, Oscar, Jr. Op. cit.

[38]The other two readers were [illegible] W. Phillips and Jean Goldstein.

2. Accordingly, informal checks were made frequently throughout the course of the readings. These informal checks consisted of the re-measurement of sections of the records and comparison of the second measurements with the first. Re-measurements were sometimes made by the same reader and sometimes by a second reader.

3. In each case of re-measurement, the measurements were called off to the recorder as in the regular measuring process discussed in the text, and the recorder, with the original data sheet in hand, halted the re-measuring after he was assured that the re-measurements did not differ materially from the original measurements. Usually each re-measurement session included approximately 15 to 20 sets of measurements of the three traces. It was intended in the event of widely divergent readings on the second measurement to record the re-measurements. No re-measurement resulted in such divergent readings, however.

Results of the informal checks on the accuracy of the measurements.

1. With the exception of a few readings of load factor, discussed below, all re-measurements of the chart agreed with original measurements with a deviation no greater than + or - 3 screen spaces. Deviations of 2 or 3 screen spaces were rare. A deviation of 1 screen space was fairly frequent, but 0 deviations were more common. A conservative estimate of the average (absolute) deviation is thus somewhat less than 1 screen space; and the average algebraic deviation, of course, approaches 0.

   This order of accuracy is quite acceptable, particularly in view of the fact that the quantitative indices take into account a large number of readings, allowing cancellation of the errors.

2. In isolated cases of very rapid changes of load factor or "vertical acceleration," measurement and re-measurement occasionally differed by as much as + or - 3 or 4 screen spaces.[39] For a single reading in the upper or middle part of the chart scale, however, (where such changes usually occur) this error would introduce an error of no more than 3° or 4°, and as little as 1°, in determining the "proper" bank. Such an error in the few readings would operate to introduce negligible error in the bank indices.

---

[39] Errors of this magnitude, occurring only when the slope of the trace is steep, would seem to be attributable chiefly to varying locations of the synchronizing scale on original and repeat readings, rather than differences in judgment; i.e., the trace was actually measured at two slightly different points on original and repeat readings.

APPENDIX B

DIFFICULTIES ENCOUNTERED IN COMPUTING THE QUANTITATIVE INDICES

APPENDIX B

DIFFICULTIES ENCOUNTERED IN COMPUTING THE QUANTITATIVE INDICES

Discarding of records.

1. Records of 4 turns (3 of one subject and 1 of another) in which the subjects misunderstood instructions were discarded, and no indices were computed for them. The first subject intentionally made medium-banked turns through a misunderstanding; the second, in executing his first turn, made a turn of only 360° through a misunderstanding.

2. In all other cases, one index of a record might be discarded owing to a particular deficiency of the record, but other indices derived from the reliable information of other traces would be computed and treated. For example, if a record displayed the "haywire" effect in the load factor trace, the bank indices were discarded, but the indices relating to lateral balance were computed in all such cases, since the wing-low traces of all records, with one exception, supplied accurate information.

Difficulties encountered in computing indices relating to "proper" bank.

1. Treatment of extreme readings of load factor.

a. Base-line readings. A base-line reading of load factor may correspond to any bank from 0° to 18°, since the load factor may be 1.05 g or any lesser value[40]. Although the indices relating to "proper" bank employed only the readings during the turn proper (that section of the turn between the first attainment of a "proper" bank of 30° and the last attainment of a "proper" bank of 30°), base-line readings of load factor nevertheless occurred occasionally: after the subject reached a bank of 30°, terminating the arbitrary entry, he might drop off bank to a point below 18°, in which case, a base-line reading, or readings, of load factor would ensue. Seventeen such instances were encountered among all the turns read.[41]

(1) In computing the mean "proper" bank during the turn proper, these seventeen cases were handled as follows: The base-line readings were first assumed to indicate a bank of 18° and mean bank was calculated. Then the base-line readings in each case were assumed to indicate a bank of 0°, and mean bank was again calculated. The two mean banks thus obtained were the most divergent possible.

---

[40]See Viteles, M. S., and Backstrom, Oscar, Jr. Op. cit.

[41]136 in number

These mean banks were then compared in order to see if the assigning of a definite value to the base-line readings was justifiable. The largest differences between the two values were: 4.23°, 3.94°, 1.97°, and 1.77°. The remainder of the differences were less than 1.5° and most of them less than 1°. In view of the small order of these differences and taking into account the fact that the true mean bank falls between the two calculated, it was not thought necessary to discard these cases.

(2) In all such cases, the value of mean bank which was obtained by equating base-line readings to 18° was employed in the statistical comparisons, since it seemed likely that the base-line readings were closer to 18° than to 0°. Moreover, in the case of the largest differences, selection of this higher value is conservative, in the sense that these larger differences were obtained in the cases of the less experienced elementary students and private pilots, who were postulated to demonstrate lower mean bank scores than the instructor group.

(3) It was impossible to apply a parallel procedure in computing the fluctuation score. Between two base-line readings of "proper" bank, the fluctuation might be as great as 18° or as little as 0°. Between a base-line reading (representing a bank anywhere from 0° to 18°) and a known reading the fluctuation might be as little as the difference between the known reading and 18°, or as great as the difference between the known reading and 0°.

If, however, as in handling mean bank, the two most divergent values possible of bank fluctuation were calculated (one value computed by assuming doubtful fluctuation values to be as large as possible and one by assuming doubtful values to be as small as possible), these two values would differ so greatly that use of either as the score would be unjustifiable. The values of the known stepwise deviations are, in general, much smaller than 18° and the inclusion of such extreme assumed values would materially increase the size of the mean fluctuation.

(4) Accordingly, in computing the mean fluctuation for these cases, all stepwise deviations derived from two doubtful values of "proper" bank were excluded. This procedure amounts to assigning to these doubtful values the value of the obtained mean of the known values. Such treatment is justifiable provided the proportion of such doubtful values is small.[42]

---

[42]It will be noted that, conversely, this procedure was impossible in computing the mean "proper" bank for these cases. It was known that the doubtful values of "proper" bank were less than the mean "proper" bank. On the other hand, these doubtful values of fluctuation might have any value throughout the range of fluctuation values, and therefore, assignment of the mean value to them is justifiable.

(5) In obtaining values of fluctuation from one known value of "proper" bank and one base-line reading, the base-line reading was assigned the value of 18°, on the basis of the evidence obtained in handling the doubtful cases for mean banks. The difference between the known "proper" bank reading and the dubious value of 18° is the least fluctuation possible between the two readings. Since th[illegible] 18° might be less than 18°, the true fluctuation might be larger than the obtained value, but it could not be smaller.

In computing bank fluctuation, if all the values of fluctuation so obtained were at the top extreme of the range of the accurate fluctuation values, the dubious values were included. To assign them the value of the mean of the accurate values (by excluding them) would not be justifiable since they obviously differed from the mean. If, however, such dubious values were scattered throughout the range of the accurate values, they were assigned the value of the mean of the accurate values (by excluding them).

(6) All cases in which the proportion of doubtful fluctuation readings exceeded 10% were discarded entirely, whether the doubtful fluctuation readings were obtained from two base-line readings of "proper" bank or from one base-line reading and one known reading. There were 5 such cases.

b. <u>Top extreme readings</u>. Two records were encountered in which values of load factor higher than the top extreme of the scale (corresponding to a "proper" bank of 61°) were obtained.

(1) In the computation of mean bank in these cases, a procedure was followed similar to that employed in treating the cases of base-line readings of load factor. The doubtful readings in these instances were equated to 70° (the reasonable extreme of bank in the type of airplane used) and a mean was calculated as a check on the mean obtained when the off-scale readings were assumed to be 61°. The difference between these two means in the one case was .16° and in the other was .64°.

(2) Bank fluctuation was not computed for one of these cases since the proportion of doubtful values of fluctuation was 30%. In the other case, the doubtful values of fluctuation ([illegible] of the total) were excluded.

2. Treatment of prop-wash effects

a. Another problem encountered in computing these indices was occurrance in some instances of prop-wash effects. It will be recalled that one of the characteristics of these effects is a fairly rapid and complete drop in the load factor curve to its base-line followed by a similarly rapid rise to approximately its former height.[43] These rapid changes in load factor are due to the accelerations of the "jolt" accompanying an encounter with the prop-wash, and do not represent changes in "proper" bank. Moreover, they are a mark of excellence and should not be treated in such a manner as to lessen the rating of the performance.

b. Accordingly, in the computation of mean bank, values of "proper" bank derived from readings of load factor during the presence of prop-wash effects were not included

c. Likewise in the computation of bank fluctuation, those stepwise deviations involving "proper" bank obtained from such readings of load factor were excluded.

3. <u>Treatment of records containing the "haywire" effect in the load factor trace</u>.

a. It will be recalled that the lack of damping of the accelerometer or load factor indicator allowed the load factor trace under certain conditions to exhibit a damping curve, and that records of load factor during such occasions are subject to much doubt of accuracy.[44] The records were inspected for this effect, and all those exhibiting it were classified according to its severity and the proportion of the record during which it persisted.

b. The bank items of all records exhibiting the "haywire" effect in a severe form, even though for merely a short time, and records exhibiting it to a slight or moderate degree for a fair proportion of the turn were discarded. The records of 20 turns (out of 136 treated) displayed this effect to an amount requiring discard of the bank indices.

The discarding procedure was qualitative in nature, but was categorical, since the effect is easily identifiable. A mild form of the effect consists in only a moderate deviation from the complex sine curve pattern of the vibrations. If the deviation persists for only a slight section of the turn, little effect can be expected on averaged measures computed from the "proper" bank values. Hence the discard could be

---

[43] See Viteles, M. S., and Backstrom, Oscar, Jr. <u>Op. cit</u>.

[44] See Viteles, M. S., and Backstrom, Oscar, Jr. <u>Op. cit</u>.

made with a high degree of objectivity. The attempt was made to discard all data which might be suspected of producing even slight inaccuracies in the computed measures.

Indices relating to lateral balance

1. Vibrations traces.

   a. The wing-low traces of the R-S instrument occasionally exhibit "spike" traces caused by vibrations.[45] Whenever these traces were encountered in measuring the record, they were identified. Readings of these vibrations traces, usually only one or two screen spaces in height, were treated as 0 readings in computing the indices relating to lateral balance.

   b. The record of one turn of one subject contained so many such traces that it was discarded.

2. Simultaneous readings of slip and skid.

   a. Occasionally, when a record exhibited a slip immediately followed by a skid, or a skid followed immediately by a slip, simultaneous readings of slip and skid were recorded. The values of each reading are invariably low: the value of one is almost always less than 2 screen spaces.

   The occurrence of these simultaneous readings of slip and skid is attributable to slight maladjustments of the transparent synchronizing scale used in reading the records, since the lag in the recording systems is negligible.[46] Occasionally, also, one of the readings is an unidentified vibrations trace.

   c. Such pairs of readings were treated by the following arbitrary rules:

      (1) If the two readings were unequal in value, the smaller one was crossed out on the data sheet and treated as a 0 reading.

      (2) If the two readings were equal in value, the one occurring at the end of a slip or skid trace was crossed out on the data sheet and treated as a 0 reading. The other one, occurring at the beginning of a slip or skid trace, was employed in computing the indices.

   d. The values of such simultaneous readings are so small that negligible effect would be produced on any index by the in-

---

[45] See Viteles, M. S., and Backstrom, Oscar, Jr. Op. cit.

[46] See Viteles, M. S., and Backstrom, Oscar, Jr. Ibid.

clusion of the one which is in fact erroneous (i.e., obtained at the wrong point in time owing to malposition of the synchronizing scale). The above treatment was therefore established in the interest of consistency rather than accuracy.

3. Single readings of slip or skid. Single readings of slip or skid (i.e., positive readings not preceded or followed by another positive reading of slip or skid) were crossed out and treated as 0 readings. Such readings are almost invariably only one screen space in height, and are likely to be erroneous judgments on the part of the reader, rather than true readings. Since there would be negligible effect on any index by their inclusion, this treatment was also established in the interest of consistency rather than accuracy.

4. Records lacking adequate signals.

   a. Records of 13 turns lacked signals to indicate the beginning or end, or both, of the turn. These records were nevertheless read; the reader selected for the arbitrarily chosen beginning a point several screen spaces before the first positive reading of load factor or for the arbitrarily chosen end, a point several screen spaces after the return of the load factor trace to its base-line.

   b. The indices relating to lateral balance were computed for all these cases. Inspection of the data sheets revealed that relatively large errors in determining these points would not affect these indices appreciably, with the possible exception of the (absolute) times spent in slipping, skidding, and lateral imbalance. In the case of the ratios corresponding to these indices (proportion of time spent in slipping, proportion of time spent in skidding, and proportion of time spent in lateral imbalance), however, the effect of such errors would also be slight. These cases were therefore included[47]

Indices relating to the time consumed in executing the turn.

1. Records lacking adequate signals.

   a. In computing the total time of the maneuver, records of 13 turns lacking either an initial signal or terminal signal, or both, were discarded. It would have been possible in such cases to assign two alternative values fo this index, one

---

[47]It is to be noted that the bank indices are not subject to this ambiguity in the cases of inadequately signalled records. The bank indices are computed only for the turn proper, which is defined with reference to the load factor trace, rather than the signal trace.

representing the least possible time of the maneuver[48] and one representing a reasonable estimated maximum possible time of the maneuver; and to make duplicate calculations using the two sets of values. In view of the grossness of this index, however, and its lack of a simple relation to pilot proficiency it was not thought that the additional labor involved in such treatment was justified.

b. In computing the time of the arbitrarily defined entry, records of 12 turns lacking an initial signal were discarded.

2. Records containing the "haywire" effect in the load factor trace. Since presence of the "haywire" effect renders the obtained values of "proper" bank inaccurate, the point of termination of the arbitrarily defined entry (i.e., the point of first attainment of a "proper" bank of 30° or greater) cannot be derived from records exhibiting this effect. The time of the arbitrarily defined entry was therefore not computed for these cases, 20 in number. (The total time of the maneuver, however, was computed for these cases, since it was obtained by reference to the signal trace alone.)

---

[48] As long as the load factor trace is above its base-line, the "proper" bank of the airplane must be 18° or greater. Hence the time during which a positive trace or load factor trace was exhibited would be the least possible time of the maneuver.

APPENDIX C

SAMPLE QUANTITATIVE RAW DATA SHEET USED IN RECORDING MEASUREMENTS OF R-S RIDE RECORDER RECORDS OF POWER TURNS

University of Pennsylvania Graphic Records Project

QUANTITATIVE RAW DATA SHEET
FOR TULANE STANDARD FLIGHT RECORDS

Instrument: R-S [illegible] Recorder

Series No. of Subject 3015 Title of Flight C! Maneuver No. 8

No. of Flight 3 Description 720° Power turn (right) at 60° bank.

i Hori-zontal Space #	ii Load factor trace, ht. in spaces	iii Indicated load factor in g*	iv L. wing low trace, ht. in spaces	v L. im-balance in °*	vi R. wing low trace, ht. in spaces	vii R. im-balance in °*	viii Sec slip or skid ∠	ix Approxi-mated Sec α	x α, angle of "proper" bank in °	xi β, fluctua-tion in "pro-per" bank in °
0	0	——	0	0	0	0	1.0	——		
1	0	——	0	0	0	0	1.0	——		
2	0	——	0	0	0	0	1.0	——		
3	0	——	0	0	2	0.8	1.0	——		
4	0	——	0	0	3	1.2	1.0	——		
5	1	1.07	0	0	1	0.4	1.0	1.07		
6	4	1.13	0	0	0	0	1.0	1.13		
7	8	1.21	0	0	2	0.8	1.0	1.21	34	——
8	12	1.29	0	0	5	2.0	1.001	1.291	39	+5
9	16	1.37	0	0	4	1.6	1.001	1.371	43	+4
10	25	1.55	0	0	2	0.8	1.0	1.55	50	+7
11	30	1.65	0	0	6	2.4	1.001	1.651	53	+3
12	34	1.73	0	0	5	2.0	1.001	1.731	55	+2
13	42	1.89	0	0	1	0.4	1.0	1.89	58	+3
14	48	2.01	0	0	0	0	1.0	2.01	60	+2
15	49	2.03	2 ∇	0	0	0	1.0	2.03	60	0
16	48	2.01	1 ∇	0	0	0	1.0	2.01	60	0
17	48	2.01	0	0	5	2.0	1.001	2.011	60	0
18	47	1.99	0	0	4	1.6	1.001	1.991	60	0
19	46	1.97	0	0	4	1.6	1.001	1.971	59	-1
20	46	1.97	0	0	1	0.4	1.0	1.97	59	0
21	48	2.01	0	0	0	0	1.0	2.01	60	+1

*St[illegible] libration [illegible]

i Horizontal space #	ii Load factor trace, ht. in spaces	iii Indicated load factor in g*	iv L. wing low trace, ht. in spaces	v L. imbalance in o*	vi R. wing low trace, ht. in spaces	vii R. imbalance in o*	viii Sec slip or skid ∠	ix Approximated Sec α	x α, angle of "proper" bank in °	xi φ, fluctuation in "proper" bank in °
22	38	1.81	0	0	1†	0	1.0	1.81	56	–4
23	36	1.77	0	0	0	0	1.0	1.77	56	0
24	34	1.73	2†	0	0	0	1.0	1.73	55	–1
25	33	1.71	0	0	1	0.4	1.0	1.71	54	–1
26	30	1.65	0	0	3	1.2	1.0	1.65	53	–1
27	30	1.65	0	0	3	1.2	1.0	1.65	53	0
28	32	1.69	0	0	2	0.8	1.0	1.69	54	+1
29	32	1.69	0	0	2	0.8	1.0	1.69	54	0
30	33	1.71	0	0	2	0.8	1.0	1.71	54	0
31	29	1.63	0	0	1	0.4	1.0	1.63	52	–2
32	29	1.63	0	0	0	0	1.0	1.63	52	0
33	29	1.63	0	0	0	0	1.0	1.63	52	0
34	28	1.61	0	0	0	0	1.0	1.61	52	0
35	33	1.51	0	0	0	0	1.0	1.51	49	–3
36	22	1.49	0	0	0	0	1.0	1.49	48	–1
37	23	1.51	0	0	0	0	1.0	1.51	49	+1
38	25	1.55	0	0	0	0	1.0	1.55	50	+1
39	27	1.59	0	0	0	0	1.0	1.59	51	+1
40	28	1.61	0	0	0	0	1.0	1.61	52	+1
41	26	1.57	0	0	1	0.4	1.0	1.57	50	–2
42	22	1.49	0	0	1	0.4	1.0	1.49	48	–2
43	25	1.55	0	0	0	0	1.0	1.55	50	+2
44	19	1.43	0	0	0	0	1.0	1.43	46	–4
45	13	1.31	0	0	0	0	1.0	1.31	40	–6
46	9	1.23	0	0	2	0.8	1.0	1.23	36	–4
47	6	1.17	0	0	4	1.6	1.001	1.171	31	–5
48	3	1.11	0	0	5	2.0	1.001	1.111		

*Static calibration

† Vibrations trace; disregard

i	ii	iii	iv	v	vi	vii	viii	ix	x	xi
Horizontal Space #	Load factor trace, ht. in spaces	Indicated load factor in g*	L. wing low trace, ht. in spaces	L. imbalance in °*	R. wing low trace, ht. in spaces	R. imbalance in °*	Sec slip or skid ∠	Approximated Sec α	α, angle of "proper" bank in °	θ, [illegible] tion in [illegible] per" bank [illegible]
49	0	——	0	0	5	2.0	1.001	——		
50	0	——	0	0	8	3.2	1.001	——		
51	0	——	0	0	11	4.4	1.003	——		
52	End of maneuver									
53										
54										
55										
56										
57										
58										
59										
60										
61										
62										
63										
64										
65										
66										
67										
68										
69										
70										
71										
72										
73										
74										

*Static calibration

EXPOSITION OF QUANTITATIVE RAW DATA SHEET

1. Column i gives the ordinal number of each horizontal projection screen space at which readings were made. Values of time were also derived from Column i in accordance with the relation

   1 horizontal projection screen space = 0.8 sec.

2. The values in Columns ii, iv, and vi were recorded during the process of measurement. From these values, the values in Columns iii, v, vii, viii, ix, x, and xi were then derived as indicated below.

3. Each vertical projection screen space in height of the load factor trace = .02 g, by static calibration. The initial tension of the accelerometer or load factor indicator = 1.05 g.

   Each value in Column iii was therefore derived from the corresponding value in Column ii in accordance with the relation

   Load factor in g = (load factor in vertical projection screen spaces) (.02) + 1.05.

4. Each vertical projection screen space in height of either wing-low trace corresponds to .40° (24 minutes) of tilt (i.e., lateral imbalance) by static calibration. Each value in Columns v and vi was therefore derived from the corresponding value in Columns iv, and vi, respectively, in accordance with the relation

   Lateral imbalance in ° = (lateral imbalance in vertical projection screen spaces) (0.40).

5. Each value in Column viii is the secant of the indicated slip or skid angle, taken from a standard trigonometric table.

6. Each value in Column ix is the product of the corresponding values in Columns viii and iii. Each product in Column ix is a close approximation to the magnitude in g of the force vector normal to the wings in the position of "proper" bank. The magnitude of this vector, expressed in gravitational units as in Column ix, is the secant of the angle of "proper" bank.

7. Each value in Column x is the angle of "proper" bank derived from the corresponding values in Column ix by means of a trigonometric table. Values of "proper" bank were rounded to the nearest whole degree.

8. Each value of fluctuation in proper bank in Column xi is the increment of each reading of angle of proper bank over the preceding reading.

9. The horizontal red lines set off the arbitrarily defined turn proper. For each record, the first red line was drawn at the point at which a "proper" bank of 30° or greater was first obtained; the second red line

was drawn at the point at which a "proper" bank of 30° or greater was last obtained. The section between the 0, or origin, space and the first red line is the arbitrarily defined entry; the section from the last red line up to and including the final reading is the arbitrarily defined recovery.

Values of angle of proper bank and fluctuation in proper bank were not derived for the arbitrarily defined entry and recovery, since indices relating to "proper" bank were computed only for the arbitrarily defined turn proper.

APPENDIX D

POSSIBLE EXPLANATIONS OF THE RIGHT-WING-LOW TENDENCY NOTED IN THE GROUPS OF SUBJECTS

APPENDIX D

POSSIBLE EXPLANATIONS OF THE RIGHT-WING-LOW TENDENCY NOTED IN THE GROUPS OF SUBJECTS

Two possible explanations have been suggested of the tendency of all groups of subjects to keep the right wing low, and that tendency may reside:

1. In the structural characteristics of the test airplane, or

2. In the subjects themselves.

Both of these possibilities are treated in detail in the following discussion.

1. The aerodynamic characteristics of the test airplane were such that it tended to fly right-wing-low.

   a. The truth or falsity of this explanation must remain in doubt. It could have been tested empirically at the field if the question had arisen or had been foreseen. The test would have consisted simply in discovering whether the airplane would maintain straight and level flight with the hands off the controls.

   b. Unfortunately, however, the problem was not foreseen. The airplane was regularly inspected and checked by a competent airport mechanic, hence there was no reason for the field experimenters to suppose that such a peculiarity might exist. The fact that the airplane was so checked and inspected however, is not acceptable evidence that the peculiarity does not exist; for the "abnormality" might be due to design and structural features beyond the comprehension of the airport mechanic.

   c. A slight difference in wing camber, or a maladjustment of the dihedral angles of the two wings, might cause the left wing to have more lift than the right. These peculiarities might not be so large as to make the plane unairworthy, but large enough to produce the tendency noted above. There are perhaps several other possible structural peculiarities which might produce such a tendency. Empirical tests on other airplanes of the same make and model,[49] or on the identical test airplane at a different time, would not serve to test this hypothesis; for even slight changes in the rigging of the airplane would seem sufficient to produce, emphasize, or correct

---

[49]The test airplane was an Aeronca Tandem trainer, Model 50-TL (a stick-type airplane).

the structural tendency postulated here.[50]

d. It is to be noted that pilots could correct for such a characteristic of the airplane, if present, by properl7 compensating control adjustments. It would be expected that instructors would be most successful in so compensating, private pilots next most successful, and students least successful. It might furthermore be expected that owing to stiffness of the controls of the test airplane, no group would be completely successful in compensating for this tendency. If the postulated peculiarity of the test airplane were present, the following results might be explained by it:

(1) The less experienced pilots (students and private pilots) slip more on the right turn than on the left.

(2) The less experienced pilots skid more on the left turn than the right.

(3) The more experienced pilots (instructors) do not exhibit a significant difference between left turn slipping and right turn slipping, or between left turn skidding and right turn skidding. That the tendency may nevertheless be present is indicated by the fact that their mean scores on the slip items of the right turn are higher (but not significantly higher) than their mean scores on the slip items of the left turn; and their mean scores on the skid items of the left turn are higher (but not significantly higher) than their mean scores on the skid items of the right turn.

2. <u>When the less experienced pilots apply right aileron, they tend to apply it to excess, and when they apply left aileron, they tend to apply it insufficiently.</u>

---

[50]Certain "background" evidence is afforded by the opinion of expert pilots as to the characteristics of the airplane. None of the instructors who flew the airplane during this experiment liked it, and this opinion is shared by every experienced pilot with whom the experimenters have subsequently discussed the characteristics of the airplane. They complain that it is "hard to fly," and that it is impossible to develop the proper "feel" because the controls are stiff and do not respond properly to slight pressures. Such complaints would seem to have no direct relation to the structural peculiarity postulated here, but the fact that the airplane was generally disliked by expert pilots indicates that these results cannot be applied to other airplanes generally.

a. The mechanism of such a tendency is suggested in pages 82-83 of the Civil Pilot Training Manual, by J. R. Cram and C. J. Brimm, Jr., Civil Aeronautics Bulletin, No. 23, September, 1940.[51] In straight and level flight, and in other situations calling for neutral aileron, the student may simply relax his right arm on the stick. The weight of the pilot's relaxed arm pulling against the stick is enough to cause a slight deflection of the right aileron; hence the right wing will be brought low.

b. In straight and level flight, this slight holding of the right wing low, instead of being corrected by the pilot, may lead to another bad habit. In order to compensate for the low right wing, he may develop the habit of holding left rudder to keep the ship directionally straight.[52] As a consequence, when a turn is started, the starting "neutral" position is not exact. This may result in a tendency to use too much rudder to the left (inducing left turn skidding) and too little to the right (inducing right turn slipping).

c. It is apparent, moreover, that not only may this slight right aileron deflection occur in supposedly neutral positions of the aileron, but also excess right aileron deflection (or insufficient left aileron deflection) may occur whenever the pilot relaxes his arm on the stick while applying slight aileron for any purpose:

(1) In a left turn, after the controls have been neutralized, a slight, fairly constant amount of right aileron must be held to correct for the overbanking tendency of the airplane. After this adjustment has been made relaxing the right arm against the stick might cause excess right aileron deflection.

---

[51]See also pages 120-121 of Civil Aeronautics Bulletin, No. 23, 2nd. Edition, September, 1941.

[52]Although it is not so stated in the Manual, it would seem that the seriousness of this compensating habit and the extent to which it is fixated might vary with the strength of engine torque in the training airplane. In American airplanes, engine torque tends to turn the airplane left, so that (assuming perfect aileron performance) it is frequently necessary to hold right rudder to offset the engine torque. It is conceivable, at least, that in the case of some airplanes that engine torque might supply a directional correction sufficient to offset the faulty right aileron deflection, and thus the student might not develop the compensating habit mentioned above (or the habit of holding right rudder to offset engine torque, either). This situation might occur particularly in the case of airplanes which are not equipped with an adjustable fin or rudder tabs to offset torque.

(2) In a right turn, after the controls have been neutralized, a slight, fairly constant amount of left aileron must be held to correct for the over-banking tendency of the airplane. After this adjustment has been made, if the right arm is relaxed, the weight of the relaxed arm may tend to pull the stick to the right,[53] and cause insufficient left aileron deflection.

(3) Thus, not only in the entry, but also in the turn proper, there may be a tendency to hold the right wing low.

d. Needless to say, however, the explanation listed under 2 need not depend upon mechanism here outlined -- namely, the relaxing of the right arm upon the stick. Any other mechanism or combination of mechanisms by which the tendency to hold excess right aileron would be brought about might also be assumed.

The postulation of this tendency to hold excess right aileron clarifies the facts which explanation under 1 accounts for, namely:

(1) The less experienced pilots (students and private pilots) slip more on the right turn than on the left.

(2) The less experienced pilots skid more on the left turn than on the right.

(3) The more experienced pilots (instructors) do not differ significantly in left and right turn slipping or in left and right turn skidding. The direction of their mean scores is in accordance with the postulated tendency, but the differences between the mean scores of the left and right turns are not significant.

---

[53] Obviously, the direction of movement of the stick in such a situation is a question of leverage. It is possible that in some left aileron deflections, the weight of the relaxed right arm may be applied to the stick in such a fashion that the stick will actually move to the left, depending on the relative direction of the force applied by the relaxed arm. This direction will, in turn, depend in part on where the stick is grasped (at the top, or lower) and the extent of its inclination to the left (i.e., the extent of the original left aileron deflection). In general, however, it would seem that relaxation of the right biceps will tend to cause movement of the stick to the right, whatever the aileron deflection before relaxation.