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STUDIES IN PILOT TRAINING: THE ANATOMY OF TRANSFER

Ralph E. Flexman, Stanley N. Roscoe,
Alexander C. Williams, Jr., and Beverly H. Williges

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Foreword

In 1949 Edwin A. Link was building more canoes than flight trainers when Paul E. Dittman, a graduate student attending the University of Illinois on a Link Aviation fellowship, prepared a sales brochure based upon the results of a transfer of training study just completed at the University's Institute of Aviation. Dittman presented his "Proof of the Pudding!" to the Deputy Chief of Staff for Personnel of the United States Air Force.

"Proof of the Pudding!" contains a clever combination of cartoons, photographs, words, numbers, and dollar signs showing how the Air Force could save money, time, and lives by capitalizing on the experimentally demonstrated transfer of "synthetic" flight training from the first "simulator" of a specific training airplane to its flying counterpart, the North American T-6/SNJ. Dittman's presentation was pivotal to the future of the Link Company, to the establishment in 1950 of the USAF Basic Pilot Training Research Laboratory at Goodfellow Air Force Base, Texas, and to the application of the unpublished results of the first of two experiments, both presented in this monograph, to the training of Air Force pilots. Few research reports have had a greater or more immediate impact than Dittman's brochure.

The second of these previously unpublished studies, both conducted by Ralph E. Flexman, was completed in 1950 just before he left the Aviation Psychology Laboratory to join the USAF Human Resources Research Center and help organize and direct the Goodfellow program. During the previous year, he and his mentor, Alexander C. Williams, Jr., had published their earlier studies of the transfer of ground-based flight training to actual flight (Williams and Flexman, 1949a; 1949b; and 1949c).

Flexman reduced the data from both experiments, and in collaboration with Williams, analyzed the data in terms of percentage of transfer from the 1-CA-2 SNJ Link to the SNJ aircraft. Before leaving the Laboratory, Flexman wrote a hasty and rough description of the experiments which I promised to put into publishable form. Williams was to write an introduction and the conclusions.

Two years later, during the summer of 1952, as I was winding things up before leaving the Laboratory, I rewrote Flexman's draft. Williams again promised to write an introduction and the conclusions for the long overdue technical report to the Special Devices Center of the Office of Naval Research.

The report still needed an introduction and conclusions in 1955 when Williams left the University of Illinois and his Aviation Psychology Laboratory to start a second career in industry. In 1962 Williams suffered a fatal heart attack, and the report was temporarily forgotten.

In the summer of 1969, while Williams' bibliography was being assembled for the first issue of this monograph series, Flexman remembered that he had a carbon copy of the original incomplete manuscript that I had sent him in 1952. The report still needed an introduction and conclusions.

During the 22 years between 1949 and 1971, Williams and some of his students and their associates had gradually evolved the concept of transfer effectiveness (Williams and Flexman, 1949b; Muckler, Nygaard, O'Kelly, and Williams, 1959; Povenmire and Roscoe, 1971; Roscoe, 1971). Fortunately Flexman's data were collected in a form that allowed Beverly H. Williges to compute the Transfer Effectiveness Ratio for each of his contact and instrument flight maneuvers. With the additional analysis of results in terms of transfer effectiveness, there was much more to be said concerning their meaning, and Mrs. Williges, who was in the second grade when this research was completed, ended up largely rewriting the body of the report.

I recently promised Flexman that I would write an introduction and the conclusions.

STANLEY N. ROSCOE
Editor

Studies in Pilot Training: The Anatomy of Transfer

Ralph E. Flexman, Stanley N. Roscoe, Alexander C. Williams, Jr., and Beverly H. Williges

INTRODUCTION

All learning is based upon a foundation of prior learning. *Transfer of training* and, more explicitly, *transfer of learning* are terms that refer to the dependence of new learning on old. How directly new learning depends on old is a function of many variables associated with the materials learned and the conditions of learning.

The Measurement of Transfer

In the training of pilots, as in the learning of nonsense syllables or the manual tracking of a sinusoidal forcing function, the efficiency of transfer of old learning to new varies widely. There is ample experimental evidence that flight training in ground-based aircraft simulators can yield high transfer to the piloting of airplanes (Caro, 1972; Caro and Isley, 1966; Creelman, 1959; Crook, 1967; Flexman, Matheny, and Brown, 1950; Flexman, Townsend, and Ornstein, 1954; Lanier and Butler, 1966; Mahler and Bennett, 1950; Payne, Dougherty, Hasler, Skeen, Brown, and Williams, 1954; Wilcoxon, Davy, and Webster, 1954; Williams and Flexman, 1949a; 1949b). However, in many of these studies transfer was expressed in general terms such as a reduction in flight failures or accidents, instructor ratings, proficiency on check rides, or overall savings in time, trials, or errors from a given amount of practice in a ground trainer. The anatomy of transfer of specific flight tasks from ground trainer to aircraft has not been systematically investigated.

Furthermore, methods of measuring pilot performance during learning and rational bases for evaluating training experiences in terms of their transfer to operational situations have been slow in emerging. The most frequently used transfer measure has been some form of percentage of transfer which deals with the degree to which learning on one task is facilitated by prior study or practice on another.

Ellis (1965) described three percentage of transfer formulas. The simplest of these reads:

$$\text{Percentage of transfer} = \frac{Y_o - Y_x}{Y_o} \times 100 \qquad [1]$$

where:

Y_o = time, trials, or errors required by a control group to reach a performance criterion after zero training units on a prior or interpolated task;
Y_x = corresponding value for an experimental, or transfer, group having received X training units on a prior or interpolated task.

Gagne, Forster, and Crowley (1948) expanded the formula such that percentage of transfer represented a percentage of total possible learning. The result was an absolute transfer scale ranging from 0 to 100 percent transfer and most likely comprised of unequal units. The general formula is:

$$\text{Percentage of transfer} = \frac{L_x - L_o}{T - L_o} \times 100 \qquad [2]$$

where:

L_o = average learning of a control group after zero training units on a prior or interpolated task;
L_x = average learning of an experimental, or transfer, group after X training units on a prior or interpolated task;
T = total possible score on the experimental, or transfer, task.

Ellis pointed out that the major difficulty with Equation 2 is that the value of T may be impossible to determine.

The third percentage of transfer formula, proposed by Murdock (1957), has the advantage of yielding a symmetrical transfer curve with definite upper and lower limits of −100 percent transfer and +100 percent transfer. The formula is:

$$\text{Percentage of transfer} = \frac{Y_o - Y_x}{Y_o + Y_x} \times 100 \qquad [3]$$

where:

Y_o = same as Y_o in Equation 1;
Y_x = same as Y_x in Equation 1.

All percentage of transfer formulas have a common fault, failing to consider the amount of practice on the prior task. They ignore the fact that economy of transfer is a negatively decelerated function of amount of prior practice. Because percentage of transfer calculations do not include prior practice, they permit no conclusions about transfer effectiveness. Realistically, however, any training program must be concerned with the transfer economy of a training device or technique.

The notion of training to a specified performance criterion in a ground-based simulator, as opposed to administering a given amount of training prior to introducing a student to a transfer task in an airplane, was first made explicit by Williams and Flexman (1949b). They also were the first to introduce the idea of transfer efficiency (Williams and Flexman, 1949b) as measured by the Transfer Effectiveness Ratio (TER) that represents the ratio of practice saved to practice spent on the prior task (Povenmire and Roscoe, 1971; Roscoe, 1971).

$$\text{TER} = \frac{Y_o - Y_x}{X} \qquad [4]$$

where:

Y_o = same as Y_0 in Equations 1 and 3;
Y_x = same as Y_x in Equations 1 and 3;
X = time, trials, or errors by an experimental, or transfer, group during prior practice on another task.

Povenmire and Roscoe (1971) experimentally demonstrated the relative transfer effectiveness of the Link AN-T-18 (the "Blue Box" of World War II) and the Singer-Link GAT-1 general aviation trainer to the Piper Cherokee airplane in the training of private pilots.

The TER permits a measure of transfer economy when a transfer group is trained to a performance criterion on a prior task. A second effectiveness measure, the Incremental Transfer Effectiveness Ratio (ITER), allows the experimenter to determine the value of successive increments of practice on the prior task.

$$\text{ITER} = \frac{Y_{x-\Delta x} - Y_x}{\Delta X} \qquad [5]$$

where:

$Y_{x-\Delta x}$ = time, trials, or errors required to reach a performance criterion by an experimental, or transfer, group having received X-ΔX training units on a prior task;
Y_x = same as Y_x of Equations 1, 3, and 4;
ΔX = incremental unit of time, trials, or errors during prior practice on another task.

The ITER gives a precise estimate of the decreasing transfer from successive increments of pretraining.

Whether *training to a performance criterion* in a ground-based simulator is efficient, as opposed to administering a specified amount of ground-based training before introducing the trainee to the transfer task, depends primarily upon the relative cost effectiveness of ground and airborne training devices. However, cost effectiveness is not the only consideration; safety, equipment availability, and similar real-world variables must be taken into account in designing a pilot training program.

Purpose of Study

To make rational judgments concerning the use of ground-based flight simulators, the detailed anatomy of transfer must be known. What sorts of flight tasks lend themselves to effective simulation and high transfer? In what order should judgmental, procedural, and perceptual-motor flight tasks be presented to maximize transfer from one task to another, whether in the simulator or in the airplane? In what way can the flight training benefits of prior practice on a particular task in a simulator be separated from the benefits of prior practice on different but similar tasks in the air? And, because both forms of prior practice facilitate learning of particular tasks in the air, how can the training curriculum be organized to maximize such facilitation?

The two experiments to be reported were designed to yield information relevant to the specific anatomy of transfer from training in ground-based simulators to the piloting of airplanes. Both percent transfer and transfer effectiveness calculations were made.

EXPERIMENT I. CONTACT FLIGHT

Because the purpose of this study was to evaluate the pattern of transfer from training in the SNJ Link trainer to retraining in the SNJ aircraft for both contact and instrument flight, two separate experiments were conducted. Although the same basic experimental design was used in both, the instructional methods and subjects used differed in some respects. Thus, the two experiments will be considered individually.

Method

Equipment. The synthetic flight trainer used was a 1-CA-2 SNJ Link trainer with cyclorama shown in Exhibit 1. This trainer qualifies as the first true simulator of a specific aircraft. The cockpit of the trainer was a salvaged forward cockpit from a wrecked SNJ-4 aircraft. All controls and instruments were operative in the normal manner except that the wobble pump did not influence fuel pressure and the radio was omitted. The mechanism of the trainer was essentially that of the 1-CA-1 Link with some engineering improvements. Flight characteristics of the aircraft were reflected in the attitude responses, instrument readings, and control pressures of the trainer. In addition, control pressures and attitude responses to control inputs were readjusted to resemble as closely as possible those of the SNJ aircraft used in the experiments. The control inputs and attitude responses of the aircraft were measured by a stopwatch and a tensiometer hooked into the control cables of the aircraft.

One unique modification of the experimental trainer was the addition of a duplicate set of essential instruments at the rear for use by the experimenter (see Exhibit 2). In order for the experimenter to score student performance, the inclusion of the second panel was essential.

Student performance was scored using the following equipment:

1. Altitude variations were scored from a sensitive altimeter.
2. Directional control was scored from a directional gyro.
3. Coordination was scored from a ball-bank indicator on which the ball tube was calibrated.
4. Bank attitudes were scored from a specially calibrated artificial horizon.
5. Nose attitudes were scored from a specially calibrated artificial horizon.

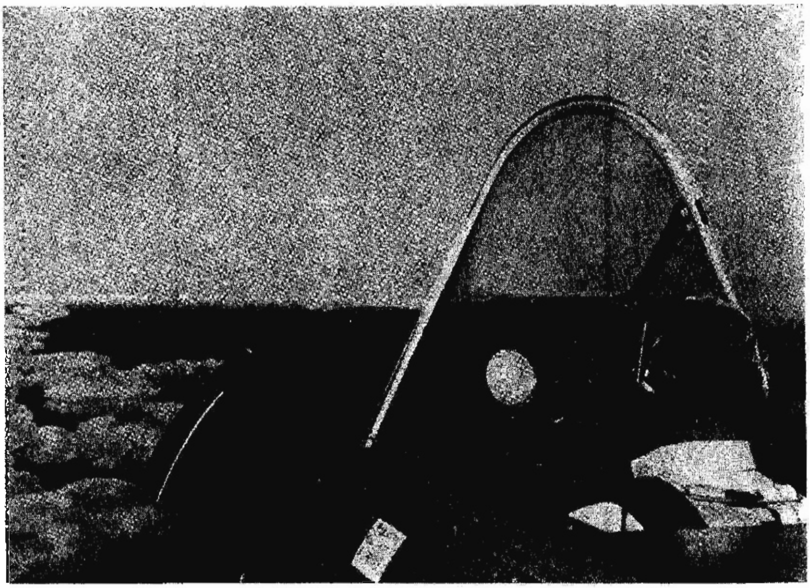

Exhibit 1. 1-CA-2 SNJ Link trainer with cyclorama used in experiment.

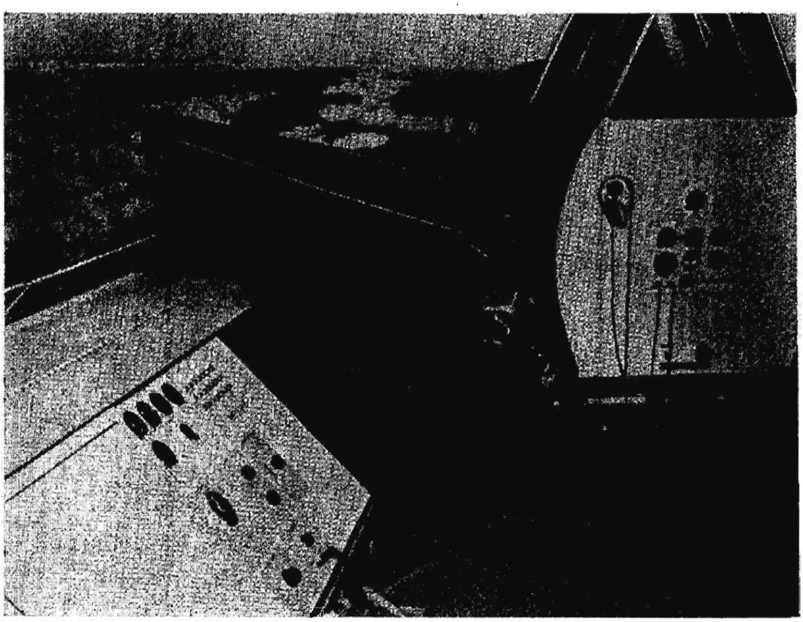

Exhibit 2. Instrument panel used by experimenter.

6. Time spent on an item was scored from a stopwatch attached to the instructor's clipboard.
7. Flight time for an exercise was scored from a clock on the instrument panel.
8. Power adjustments were scored from a standard tachometer and a manifold pressure gauge.
9. Procedure items were scored by reference to a checklist on the grade sheet.

Subjects. Twelve subjects were used. Equipment and time limitations restricted subjects to this small number; the experiment had to be completed in one semester, and only one trainer and one aircraft were available for use. All of the subjects were male students of the University of Illinois at Urbana-Champaign and ranged in age from 21 to 36 years. None had any previous flight instruction or flight experience except as a passenger. The primary basis for subject selection was the statement that each would be able to continue with the experiment until it was completed. In addition, each was required to pass a physical examination.

Experimental groups. In order to estimate the extent to which various skills learned in a ground-based trainer transfer to flight, it was necessary to measure two things: (1) the amount of practice required to relearn flight maneuvers to predefined levels of proficiency in the aircraft after they had been learned in the Link trainer and (2) the amount of practice required to learn the same flight maneuvers to the same levels of proficiency in the aircraft without previous practice in the trainer. Consequently, two groups of students were used. The group that received instruction both in the trainer and in the aircraft was called the Transfer Group (T), and the group that received instruction only in the aircraft was called the Control Group (C).

Assignment of students to Transfer Group or Control Group was based in part on their scores on the Bennett-Fry Mechanical Comprehension Test. This test was one of a battery used to select Naval Aviation Cadets during World War II. It is known to correlate acceptably with success in Naval primary flight training. Because its correlation with ability to perform the maneuvers used in this experiment was unknown, the statistical results of the experiments were not treated as though they reflected the performances of matched groups. Whatever matching may have been accomplished

Exhibit 3. Scores of Transfer and Control Groups on Bennett-Fry Mechanical Comprehension Test.

Student	Transfer Group	Control Group
1	61	58
2	55	56
3	50	52
4	43	47
5	41	40
6	40	37

Note: The means of both Transfer and Control Groups were 48.33.

by this method added an unknown increment to the precision of the results. The scores made on this test are shown in Exhibit 3.

A factor influencing the composition of each group was the students' availability for instruction. This was necessary to insure equal group representation in morning and afternoon flights.

Procedure. Transfer subjects were trained to criterion on each exercise first in the Link and then in the air. The procedure was adopted to be able to compare the two groups on each exercise. Had the Transfer Group learned all exercises in the trainer before flying the aircraft, an exercise-by-exercise comparison would not have been legitimate, because the Transfer Group would have had the benefit of practice on subsequent exercises in the Link.

The material learned by each group was divided into 13 exercises:

1. Cockpit familiarization
2. Cockpit check
3. Starting procedure
4. Run-up check
5. Effect of controls
6. Straight and level flight
7. Trimming the aircraft; power and speed changes
8. Level turns
9. Straight climbs and glides
10. Climbing and gliding turns
11. Stalls (seven)
12. Entry to the traffic pattern
13. Flying the traffic pattern

In most instances the experimental subjects completed an exercise in the Link on one day and then attempted the exercise in the aircraft two days later. If on the third day the flight were cancelled, the student had to retain what he had learned in the Link over a period of four days. This should not have been a significant handicap, because the results of other transfer experiments using similar tasks indicate that transfer effects can bridge gaps of many days or even weeks. In any case, adverse effects due to delays in training should have affected both groups equally because equal numbers of subjects from each group were scheduled each day.

Flight periods were generally limited to a maximum of one hour. However, during the last few exercises a flight period was occasionally extended an extra half-hour.

The subjects were not allowed to fly the airplane when climbing to flight altitude or returning to the field if such experience would have resulted in practice applicable to an exercise not yet completed. Otherwise this type of "extra" flying was allowed in an attempt to maintain the subject's interest in the experiment. Because all flight time was recorded as exercise time, this extra flying was not considered important.

Excluding Exercises 12 and 13, all flight exercises were performed in smooth air so that turbulence would not affect the ball-bank or vertical-speed indicators. This required smooth air to be found, resulting in the exercise being performed at varying altitudes. Visibility had to be adequate for each exercise, and a minimum of five miles was established.

All subjects were informed that they were to notify the instructor whenever they did not feel well enough to make a flight; if during the flight they experienced any airsickness, the exercise was stopped. Except for several subjects experiencing slight nausea on their first rides in the SNJ, no airsickness was reported.

To reduce the variability due to instructors, the same instructor trained both the Transfer and Control Groups. Except for Exercises 12 and 13, entry into the traffic pattern and flying the traffic pattern, all instruction was given in flight or in simulated flight so that instruction time would be a component of exercise time. In all cases instruction was held to a minimum.

Generally, when a new exercise was presented to the Control Group, the first recorded trial was a demonstration by the instructor. For the Transfer Group, the first recorded trial for a new exercise was in the Link, and the instructor "talked" the subject through the trial. On his first trial in the aircraft, a transfer subject received no assistance from the instructor. If a subject in either group persisted in an error or indicated lack of orientation after three consecutive trials, the instructor again demonstrated the maneuver. At the end of each trial a subject was told whether or not the trial was successful; if errors were made, he was told what the errors were and how they could be corrected. The instruction given transfer subjects in the Link paralleled that given control subjects in the aircraft as much as possible. In Exercises 12 and 13 all subjects had to verbalize the procedures and demonstrate the patterns with blackboard drawings before attempting the exercises in the Link or the aircraft.

As events occurred, scores were recorded on grade sheets developed in a preliminary study. Prior to the main experiments, the instructor practiced grading procedures with four preexperimental subjects. The first was an experienced SNJ pilot with a commercial pilot rating. The second subject was a private pilot with no experience in the SNJ aircraft. The third and fourth subjects met the requirements of the regular experimental subjects. One of these two subjects was trained as the Transfer Group subjects were later trained and the other as the control subjects were trained. The performances of these preexperimental subjects, aside from providing grading practice for the instructor, served to determine whether or not performance within the tolerances established for the 370 performance items was attainable within a reasonable time limit.

Performance measures. Students were required to practice each exercise until it could be performed three consecutive times without error. When an exercise consisted of more than one part, each part was practiced as if it were a separate exercise. Performance was measured in three different ways yielding three different indices of learning. The three measures were:

1. *Number of trials* required to reach the criterion of three errorless trials. A trial was defined as one performance of an exercise or exercise part.
2. *Number of errors* made before reaching criterion. An error was defined as a performance of any required operation not meeting the criterion level of proficiency.
3. *Amount of time* devoted to practice and instruction in flight to reach criterion performance.

An error in performance was scored in the following way: Each exercise or maneuver was divided into a number of operations believed to be critical to adequate performance of the maneuver. These items were defined operationally, that is, in terms of the actual operations required of the subject. For each item, a criterion for correct performance was established based upon both experience with preexperimental subjects and generally accepted performance standards. The criteria were of two types. The first type, applicable chiefly to procedural items, simply required a yes-no judgment on the part of the experimenter; either the subject performed the operation as required or he did not. For the second type of criterion, used chiefly with the flight control items, specific tolerances were established within which performance was scored as correct.

Performance was scored objectively by reference either to rigidly defined procedures or to specially calibrated instruments. A complete listing of all performance items and their respective criteria is given as Appendix A, and errors on each item are tabulated.

Results

Transfer of training was measured in two ways. First, percentage of transfer was calculated using a variation of the transfer measure suggested by Gagne, Forster, and Crowley (1948) and given earlier as Equation 2.

$$\text{Percentage of transfer} = \frac{Y_o - Y_x}{Y_o - N} \times 100 \qquad [6]$$

where:

Y_o = same as Y_o in Equations 1, 3, 4, and 5;
Y_x = same as Y_x in Equations 1, 3, 4, and 5;
N = constant denoting smallest amount of time, trials, or errors possible before reaching a performance criterion. (In these experiments, N always equals zero, indicating that it is theoretically possible to learn the tasks without any practice if criterion trials are not counted.)

The second transfer measure used was the TER given earlier as Equation 4.

The three errorless criterion trials and the time consumed by them are not included in any of the values presented. Only the number of trials and practice time required to reach the criterion level of performance on each exercise are given.

Results of the contact flight experiment are summarized in Exhibit 4. Given are the total number of errors made and the total number of trials and amount of time required by each group to learn to perform all 13 exercises at criterion proficiency in the SNJ

Exhibit 4. Summary of transfer of training in errors, time, and trials for the contact flight experiment.

Item	Errors	Time	Trials
Link Trainer (T)	847	2960	774
SNJ Aircraft (T)	564	1677	544
SNJ Aircraft (C)	2076	4293	1418
Saving in Aircraft	1512	2616	874
Percent Transfer	73	61	62
Transfer Effectiveness	1.79	0.88	1.13

aircraft. The exhibit also shows errors, trials, and time required by the Transfer Group to learn the exercises in the Link trainer. Amount of transfer is expressed as absolute savings, percentage of transfer, and transfer effectiveness.

Transfer of training from the SNJ Link to the SNJ aircraft resulted in error, time, and trial savings of 73, 61, and 62 percent, respectively. In general, students in the Transfer Group who first learned to perform the maneuvers in the Link required only one-third as much training in the airplane as students in the Control Group.

The differences between the speeds of learning in the aircraft for the two groups were statistically significant ($p < .001$). In fact, there was no overlap whatever between the members of the two groups, the poorest student in the Transfer Group learning faster than the best student in the Control Group as indicated by each of the three measures.

The transfer effectiveness of Link training expressed in terms of time indicates that each hour of Link training saved 0.88 hour of flight time. An error in Link training saved 1.79 errors in the air, and a trial in the Link saved 1.13 trials in the air.

Of the 13 exercises taught in the experiment, the first 4 were procedural exercises performed with the airplane on the ground, whereas all other exercises were performed in flight. The average saving of flight time devoted to learning Exercises 5 through 13 was 5.56 hours for a flight syllabus normally requiring 10 hours. This represents a saving of approximately 56 percent compared with the 61 percent saving obtained when times for ground exercises are included. The 10-hour flight syllabus includes only the time actually spent by the Control Group practicing the various exercises in flight. It excludes not only flight time for criterion trials but also times spent by the instructor in taking off, climbing to flight altitude, maneuvering into position for successive trials, giving verbal instructions between trials, descending, landing, and returning to the parking area at the end of each flight.

The absolute savings, percent transfer, and transfer effectiveness in errors, exercise time, and trials for each of the 13 exercises are given individually in Exhibit 5. The 13 exercises were classified in three categories: procedural exercises performed on the ground (Exercises 1–4), contact airwork exercises performed in flight (Exercises 5–11), and ground-referenced exercises performed in flight (Exercises 12–13). Comparable savings were obtained for each of the three types of exercises studied. However, this finding does not justify the conclusion that comparable savings would be obtained for other types of exercises that might be taught in a Link trainer.

An inspection of the results for individual exercises shows that savings on all exercises were approximately the same with the exception of Exercise 8, level turns, on which savings were considerably less than on other exercises.

Exhibit 5. Percent transfer (PT) and transfer effectiveness ratio (TER) for errors, time, and trials for each exercise.

Exercise	Errors		Time		Trials	
	PT	TER	PT	TER	PT	TER
1. Cockpit Familiarization			96	1.16		
2. Cockpit Check	79	1.10	97	0.97	57	0.67
3. Starting Procedure	84	2.61	83	1.35	84	1.71
4. Run-up Check	91	3.03	60	0.92	76	1.15
All Procedural Exercises	88	2.70	83	1.08	78	1.30
5. Effect of Controls	84	1.07	70	0.64	73	0.62
6. Straight and Level Flight	79	0.84	79	0.54	76	1.07
7. Trimming the Aircraft; Power and Speed Changes	84	2.60	67	1.07	72	1.05
8. Level Turns	55	1.26	35	0.50	40	0.82
9. Straight Climbs and Glides	67	2.71	60	1.30	62	1.52
10. Climbing and Gliding Turns	62	4.48	48	1.21	59	2.53
11. Stalls	67	2.91	48	0.75	60	1.64
All Contact Airwork Flight Exercises	69	1.68	55	0.81	61	1.12
12. Entry to the Traffic Pattern	70	0.94	74	0.58	68	0.72
13. Flying the Traffic Pattern	84	1.69	64	1.93	57	1.18
All Ground-Referenced Flight Exercises	80	1.40	67	1.07	61	0.94
ALL EXERCISES COMBINED	73	1.79	61	0.88	62	1.13

More detailed results are presented separately for each exercise in the following sections. Exhibits summarize the number of errors, amount of time, and the number of trials required by each group to learn to perform the exercise at the criterion level of proficiency in the aircraft. Similar information is given on the Transfer Group's performance in Link training. These results are summarized as absolute savings, percentage of transfer, and transfer effectiveness.

Exercise 1. Cockpit familiarization. This exercise was the subject's first introduction to either the Link or the aircraft. The recording of exercise time started when the subject entered the cockpit and stopped when he came out. Errors were not recorded, and the exercise was performed only once by each subject. The instruction phase of this exercise included a detailed explanation of every instrument, switch, and control in the cockpit including its function, range of movement, and normal setting. The sequence in which these items were pointed out corresponded to a definite and logical trip around the cockpit starting with the brake pedals; moving along the floor to the gas gauges; up through the seat including parachute, safety belt, and radio equipment; then across the left side of the cockpit to the upper instrument panel; and, finally, to the lower instrument panel.

The subject was then allowed to ask any questions he desired concerning the items. When the subject was ready, the instructor called out a special group of items (those items the student would be required to locate in the next exercise) and required the subject to locate the items. If the items were correctly located, the subject was to explain or demonstrate their functions, movements, and normal settings. If the subject failed to locate or adequately explain an item, additional instruction was given until the subject could locate and explain all items with equal facility.

The Transfer Group had an absolute saving of 228 minutes over the Control Group's performance, a difference that is significant at the .001 level. Saving in time can also be expressed as 96 percent transfer or 1.16 transfer effectiveness. It is interesting to note that in this exercise and in many other instances an hour of training in the Link was worth more than an hour of training in the aircraft.

Exercise 2. Cockpit check. This exercise was designed to ascertain whether or not the subject could quickly and accurately locate all of the cockpit items. The testing procedure used allowed each subject to sit in the cockpit and practice as long as he desired; then he was blindfolded and his accuracy in locating items was checked. Before the subject started his practice period, the test procedure was explained to him so that his practice might be better directed. The practice period was timed and recorded as part of the exercise time. During the test itself, items were called out in the sequence in which they had been given in Exercise 1. The subject was allowed 10 seconds to locate an item correctly. If he failed, the next item was called out, and the missed item was relocated at the end of the test. The subject was further required to adjust or set those items that would allow such manipulation, such as trim tabs, throttle, and so forth. In this exercise, criterion performance was one successful trial.

Transfer subjects had overall savings in errors, time in seconds, and trials of 11, 145, and 4, respectively. Differences in errors and trials were significant at the .05 level, and time differences were significant at the .001 level. Error savings reflected 79 percent transfer or a TER of 1.10. Exercise time yielded 97 percent transfer or a TER of 0.97, and trials saved resulted in 57 percent transfer or a TER of 0.67.

Exercise 3. Starting procedure. In this exercise students in the Transfer Group had the advantage of massed practice for they continued practicing the exact starting procedure in the Link until the three-successful-trials criterion was met. However, when performing the exercise in the SNJ, both groups were allowed only one trial per scheduled flight. Massed practice was prohibited in the SNJ because of the drain on the battery during the starting procedure.

The first time students in the Control Group attempted the exercise, they received one demonstration and one trial and after that did not receive any additional demonstrations unless consistent errors were made in three successive trials. It is to be noted that the students in the Transfer Group received extra practice on this exercise because, every time they flew the Link, they were required to use correct starting procedures.

It is very important in starting the engine of the SNJ that the correct procedure be followed, not only to assure successful starting, but because a potential fire hazard exists if the pilot fails to use the proper procedure. With this in mind, an error was recorded if the subject deviated in any way from the prescribed sequence of events in the starting procedure. Only one error was scored regardless of how many items were attempted out of the correct sequence. However, if the engine failed to start when the energizer was engaged, the time being recorded on the exercise was stopped until the subject reached that point on his next trial. (This second trial was not recorded because the usual remedy merely consisted of additional prime and reenergizing.)

Once the engine was running, the subject was required to keep it running by correct use of the primer and throttle. As in all the exercises, at the end of a trial in which errors were made, the errors were pointed out to the subject, and methods for correcting them were suggested. All items on this exercise had to be called out by the subject as they were being performed.

Results indicate that massed practice is beneficial for learning starting procedures. Differences in time, trials, and errors between the Transfer and Control Groups were all significant at the .001 level. Percent transfer for each of the dependent variables was approximately 84 percent. However, the most revealing information is the transfer effectiveness measure of 2.61, 1.35, and 1.71 on errors, time, and trials, respectively. These numbers indicate that with the massed practice available in the Link, the Transfer Group required much less practice than the Control Group to learn starting procedures even when amount of practice in the Link is a factor in transfer effectiveness calculations.

Exercise 4. Run-up check. As in Exercise 3, the Transfer Group learned the exercise to criterion in the Link and then had one trial per flight in the SNJ aircraft. The Control Group received a demonstration and one trial the first day. After the first trial, this group again received only one trial per scheduled flight.

During performance on the exercise, exact procedure was required, and each item was called out by the subject. Those items that required manipulation during the run-up check, such as the throttle when the functioning of the magnetos was being tested, had to be performed correctly or an error was scored. The Transfer Group had a special advantage in this exercise, because a run-up check was required in the Link on every scheduled training flight. This was desirable to assure correct functioning of the Link, although not all the items of the check were important. However, if only necessary items were included in the trainer check, the learning of this incorrect procedure might have interfered with correct performance in the aircraft.

Massed practice again yielded superior performance over the performance of students receiving only distributed practice. Differences in practice required in the aircraft were all significant ($p < .001$).

Percent transfer for errors, time, and trials was 91, 60, and 76 percent, respectively, and TERs were 3.03, 0.92, and 1.15, respectively.

Exercise 5. Effect of controls. Before any subject attempted this exercise, he was thoroughly briefed on the effects on the airplane of control movement and pressure. After the subject had his first trial on Parts A-1, A-2, and A-3 (use of elevator, aileron, and rudder), adverse yaw effect of the ailerons, skids and slips, and the nose-low effect of too much rudder were explained. Such adverse effects of incorrect control usage were pointed out as they occurred during the subject's next two trials.

Prior to performance on Part B (coordination of aileron and rudder), an explanation was given on the need to coordinate aileron and rudder pressures to establish a banked attitude and the necessity of neutralizing controls when desired attitude is attained. The correct degree of bank for this maneuver was approximately 30 degrees.

In Part C (power adjustments), the subject was told to raise his hand when he had made what he thought was the correct adjustment. The effect of r.p.m. on manifold pressure was pointed out to both groups. In addition, the Transfer Group was informed that in the Link this effect was not simulated.

In Part D (coordination of r.p.m. and manifold pressure), correct procedures for increasing or decreasing a power setting were explained to the subject prior to his first trial. The interaction of manifold pressure and r.p.m. was pointed out. A change in r.p.m. would always result in a concomitant change in manifold pressure, but changing manifold pressure itself would not change r.p.m. except for a momentary surge. When Part D was attempted in the Link, the pitching movement of the trainer was restricted to simplify the subject's task of flying level. In the SNJ, the instructor assisted the student in maintaining straight and level flight. When directions were given to change a power setting, the references made were to slow cruise, fast cruise, or normal cruise. Timing started when the instructor first noted a change in either the tachometer or manifold pressure gauge and ended when the student raised his left hand.

Instruction given to the subject before Part E (trim tab adjustments) was attempted consisted of pointing out a reference for pitch attitude that the subject was to use to help maintain level flight. When the subject had established this reference, he was told that his task consisted of keeping the present attitude while adjusting the trim tabs to various settings. The trim conditions required were from a nose-heavy position back to a point at which no pressure was required on the elevator to maintain the level attitude and from a nose-light position back to the neutral position. The rudder trim was used in the same way. The subject also was told to move the trim tabs at least three inches when establishing an off-trim position so that positive control pressures would be necessary to maintain level flight.

With the exception of performance on Part B, coordination of aileron and rudder, Link training resulted in significant transfer to performance in the air as shown in Exhibit 6. When performances on all parts were summed, practice differences between the Transfer and Control Groups were significant at the .001 level. On Part B, however, transfer was not so great. Although transfer was 33, 50, and 61 percent for errors, time, and trials, respectively, TERs were

Exhibit 6. Summary of results for Exercise 5: Effect of controls.

Item	A	B	C	D	E	Sum
			ERRORS			
Link Trainer (T)	0	53	3	18	2	76
SNJ Aircraft (T)	0	8	0	7	1	16
SNJ Aircraft (C)	5	12	7	61	12	97
Saving in Aircraft	5	4	7	54	11	81
Percent Transfer	100	33	100	89	92	84
Transfer Effectiveness	[a]	0.08	2.33	3.00	5.50	1.07
			TIME			
Link Trainer (T)	38	112	15	70	29	264
SNJ Aircraft (T)	10	13	4	39	6	72
SNJ Aircraft (C)	26	26	48	109	31	240
Saving in Aircraft	16	13	44	70	25	168
Percent Transfer	62	50	92	64	81	70
Transfer Effectiveness	0.42	0.12	2.93	1.00	0.86	0.64
			TRIALS			
Link Trainer (T)	1	58	4	10	6	79
SNJ Aircraft (T)	0	7	0	9	2	18
SNJ Aircraft (C)	5	18	9	23	12	67
Saving in Aircraft	5	11	9	14	10	49
Percent Transfer	100	61	100	61	83	73
Transfer Effectiveness	5.00	0.19	2.25	1.40	1.67	0.62

[a] Because the divisor in the equation would be zero, a TER cannot be calculated.

only 0.08, 0.12, and 0.19, respectively. In other words, a large amount of Link practice was necessary to produce even minimal savings in air trials. These results emphasize the need to employ transfer measures, such as the TER, that take into account amount of practice on the prior task.

Exercise 6. Straight and level flight. In the air, the instructor made preparations for this exercise by adjusting the power settings for normal cruise and setting the trim tabs for straight and level flight. In the Link, the subject trimmed up the trainer and made the correct power settings before the exercise started.

Timing on the exercise began when the instructor first started to point out the various references available to the subject in determining a flight attitude. The first demonstration was straight and level flight. Level flight was determined by the position of the nose or engine cowling in relation to the horizon. The instructor then checked to be sure that the subject was able to recognize level flight by varying attitude slightly and asking the subject to hold up his hand when the exact attitude was reestablished. Following this, the use of the altimeter as an aid in maintaining level flight was explained and demonstrated.

Level flight in relation to movement about the longitudinal axis was also explained and demonstrated. The primary reference here was the relation of the two wing tips to the horizon, and the secondary reference was the bank indicator of the artificial horizon.

The primary reference for straight flight was the relation of the longitudinal axis of the aircraft to a section line. Once this relationship was apparent to the subject, the use of the directional-gyro compass was explained and demonstrated emphasizing that this compass was a secondary reference.

The effect of torque in relation to airspeed changes and its effect on directional control of the airplane were demonstrated and the corrections explained. These demonstrations included the effect of torque when recovering from climbing and gliding turns. Also, the "heaviness" of the controls as a function of airspeed was pointed out. For students in the Transfer Group, these demonstrations were given in the Link trainer only.

The aircraft was then flown into various attitudes by the instructor, and the subject was required to return it to straight and level flight. The subject was told to raise his left hand as soon as he determined that level flight had been reestablished, thus completing the trial. This procedure allowed the instructor to check the time required for the trial. Time started with a signal from the instructor and ended when the subject raised his left hand. The maximum time allowed to return to straight and level flight was 10 seconds. The attitudes from which the subject was to return to straight and level flight were predetermined and were set up by reference to the artificial horizon and the airspeed indicator. Likewise, the degree of straightness and levelness to which the subject was to return was graded by reference to preestablished norms on the artificial horizon and directional gyro.

Recovery from a nose-high attitude, wing-low attitude, nose-low attitude, steep climbing turn, and a steep diving turn were given as the tasks in Parts A, B, C, D, and E, respectively. Each part was graded as a separate unit for trials and errors, but all parts of the exercise were graded as a single unit on the time measure.

The results for Exercise 6 show consistently high transfer from Link training to in-the-air performance. Overall differences in errors, time, and trials were significant ($p < .001$). Percent transfer ranged from 66 to 100 percent, and transfer effectiveness ranged from 0.54 to 1.26, as shown in Exhibit 7.

Exercise 7. Trimming the aircraft; power and speed changes. Instruction on this exercise included a review of the importance of using cues outside the cockpit when attempting to maintain straight and level flight and emphasized the fact that instruments in the cockpit were to be used only to make certain that an attitude was correct. The effect of different power settings on directional control and nose heaviness was also explained.

Prior to turning the controls over to the subject, the airplane was lined up with a section line and trimmed for level flight. In Part A the subject's task was to hold straight and level flight for two minutes. If corrections were necessary to reestablish the desired heading, they were to be made with coordinated aileron and rudder movements. Likewise, if altitude corrections were necessary, they were to be made by changing the nose attitude of the airplane and checking the altimeter, keeping in mind that the return to level flight had to be a gradual change as the airspeed returned to normal. In this part of the exercise, the subject was to maintain straight and level flight for a period of two minutes with the instructor taking over at the end of the period. No demonstration trials were given to either group.

In Part B the subject took over the controls at a particular altitude and heading with the airplane trimmed for straight and level

Exhibit 7. Summary of results for Exercise 6: Straight and level flight.

Item	A	B	C	D	E	Sum
			ERRORS			
Link Trainer (T)	15	23	18	70	54	180
SNJ Aircraft (T)	1	9	0	23	8	41
SNJ Aircraft (C)	14	28	11	86	54	193
Saving in Aircraft	13	19	11	63	46	152
Percent Transfer	93	68	100	73	85	79
Transfer Effectiveness	0.87	0.83	0.61	0.90	0.85	0.84
			TIME [a]			
Link Trainer (T)						293
SNJ Aircraft (T)						43
SNJ Aircraft (C)						201
Saving in Aircraft						158
Percent Transfer						79
Transfer Effectiveness						0.54
			TRIALS			
Link Trainer (T)	18	24	24	62	58	186
SNJ Aircraft (T)	2	11	0	34	16	63
SNJ Aircraft (C)	19	32	15	112	84	262
Saving in Aircraft	17	21	15	78	68	199
Percent Transfer	89	66	100	70	81	76
Transfer Effectiveness	0.94	0.88	0.63	1.26	1.17	1.07

[a] Not broken down by parts.

flight. His instructions were to rotate the elevator trim tab slowly about three inches in one direction and the rudder trim tab about three inches in the opposite direction. Altitude and heading were held constant while changing the trim tabs, and the instructor assisted when necessary. When the trim tabs were properly offset and the altitude and heading correct, the subject was told to retrim the airplane as quickly as possible and to maintain his present altitude and heading. As soon as the airplane was retrimmed, the subject was to hold both hands above his head until the instructor told him to lower them. The purpose of this procedure was to allow the instructor to determine when the subject finished retrimming the airplane and to determine whether or not the aircraft was properly trimmed. The criterion of correct retrimming was that the aircraft maintain straight and level flight within the prescribed limits for a 10-second period of "hands-off" flight. Altitude and heading were recorded twice. The first recordings were made as soon as the subject removed his hands and feet from the controls and the second when the 10-second period was over. The control subjects received a demonstration trial on this part of the exercise before their first attempted trial.

Three changes in power settings were required in Part C. The first was to establish slow cruise and then hold heading and altitude for one minute at this power setting; the second was to proceed to a fast cruise power setting, again holding altitude and heading for one minute; the third was to return to normal cruise. Prior to the demonstration trial on this part of the exercise, the subject was reminded of the effect on directional control of changes in airspeed. The subject was told when to start a trial, and he held up his left hand when the new power setting was established. The instructor graded errors of heading and altitude made while the subject was establishing a power setting. After the new power was established, the subject was to maintain altitude and heading for one minute, at which time the instructor again graded errors, reestablished the original altitude and heading, and then told the subject to proceed on to the next power setting.

Overall practice differences ($p < .001$) and practice differences on Parts B and C ($p < .01$) were significant. However, the difference in practice on Part A was not significant, and TERs for each dependent variable in Part A were rather low (0.64, 0.37, and 0.36 for errors, time, and trials, respectively), as shown in Exhibit 8. This exception might have resulted from the need in Part A to coordinate aileron and rudder movements, a task which resulted in little transfer when originally introduced in Exercise 5.

Exercise 8. Level turns. Preliminary instructions for this exercise included additional emphasis on the necessity of flying by attitude and using instruments only as a check on the correctness of attitude being held. The two instruments to be checked in a turn were the bank indicator of the artificial horizon and the altimeter. It was necessary for the subject to use the bank indicator in the Link, because the physical limitations of the trainer would not permit an actual bank in excess of 17 degrees. However, in relation to airspeed effect, control pressures, and gyro-horizon indication, a simulated bank of 55 degrees was possible. The subject was given further instruction on the coordination of controls on entry and recovery from

Exhibit 8. Summary of results for Exercise 7: Trimming the aircraft; power and speed changes.

Item	A	B	C	Sum
		ERRORS		
Link Trainer (T)	11	28	50	89
SNJ Aircraft (T)	6	5	32	43
SNJ Aircraft (C)	13	83	178	274
Saving in Aircraft	7	78	146	231
Percent Transfer	54	94	82	84
Transfer Effectiveness	0.64	2.79	2.92	2.60
		TIME		
Link Trainer (T)	90	116	188	394
SNJ Aircraft (T)	37	28	141	206
SNJ Aircraft (C)	70	169	388	627
Saving in Aircraft	33	141	247	421
Percent Transfer	47	83	64	67
Transfer Effectiveness	0.37	1.22	1.31	1.07
		TRIALS		
Link Trainer (T)	25	37	37	99
SNJ Aircraft (T)	10	8	23	41
SNJ Aircraft (C)	19	61	65	145
Saving in Aircraft	9	53	42	104
Percent Transfer	47	87	65	72
Transfer Effectiveness	0.36	1.43	1.14	1.05

turns and the anticipation of the necessary additional elevator pressures as airspeed decreases during a turn.

Before the subject's first trial on Part A (90-degree level turn), the airplane was lined up with a section line, correctly trimmed, the desired altitude established, and the directional gyro set on zero. On successive performances of the exercise, the direction of the turn was alternated.

Part B of the exercise was performed in the same manner as Part A except that a 180-degree turn was required instead of a 90-degree turn.

When the subject reached Part C (180-degree level turn in slow flight), he was again reminded of the effect of power changes on directional control and nose heaviness. The subject started his trial by setting up slow-flight power and holding straight and level flight until the instructor told him to begin the turn. This procedure was necessary to give the instructor an opportunity to grade the first phase of the trial. The trial was considered complete when the turning motion of the airplane was stopped.

The instructions given to the subject before he attempted Part D (360-degree steep turn) were designed to prepare him for the necessity of increasing the elevator control pressure during the steep turn. During performance of this last part of the exercise, the degree of bank could be off momentarily as much as 10 degrees without an error being scored. However, if the degree of bank remained off more than 5 degrees for longer than 45 degrees of turn, an error was scored. This unusual grading procedure was necessary to allow the subject to recover from an incorrect nose attitude by shallowing or steepening the bank without an error being scored. Finally, if the instructor observed that an error was made due to the airplane's encountering its own "prop-wash," an error was not recorded.

Exhibit 9. Summary of results for Exercise 8: Level turns.

Item	A	B	C	D	Sum
			ERRORS		
Link Trainer (T)	75	33	49	14	171
SNJ Aircraft (T)	47	72	11	45	175
SNJ Aircraft (C)	152	60	51	128	391
Saving in Aircraft	105	−12	40	83	216
Percent Transfer	69	−20	78	65	55
Transfer Effectiveness	1.40	−0.36	0.82	5.93	1.26
			TIME		
Link Trainer (T)	145	63	162	74	444
SNJ Aircraft (T)	63	188	25	136	412
SNJ Aircraft (C)	168	103	133	228	632
Saving in Aircraft	105	−85	108	92	220
Percent Transfer	63	−83	81	40	35
Transfer Effectiveness	0.72	−1.35	0.67	1.24	0.50
			TRIALS		
Link Trainer (T)	63	30	40	21	154
SNJ Aircraft (T)	39	99	7	47	192
SNJ Aircraft (C)	121	56	42	100	319
Saving in Aircraft	82	−43	35	53	127
Percent Transfer	68	−77	83	53	40
Transfer Effectiveness	1.30	−1.43	0.88	2.52	0.82

Although performance differences for the Transfer and Control Groups were significant at the .01 level for errors and the .05 level for trials, no significant difference in exercise time was measured. The apparent source for the overall low level of transfer seems to be Part B of the exercise (180-degree level turns). Percent transfer, transfer effectiveness, and absolute savings in errors, time, and trials were all negative on Part B. The Transfer Group required more practice than the Control Group to reach criterion on 180-degree turns, whereas the reverse was true for 90-degree turns (Exhibit 9).

Exercise 9. Straight climbs and glides. Prior to the subject's first trial on this exercise, the tolerances for airspeed, altitude, and the ball of the turn-and-bank indicator were explained. The subject was reminded of the torque effect in relation to airspeed and power changes, and the use of the ball as a reference to determine the adequacy of torque correction was demonstrated.

In the demonstration trial, the proper climbing attitude and procedure for entry to and recovery from a climb were pointed out to the subject. A trial in Part A (1500-foot straight climb) started when the nose was raised for the climb and was considered complete when the power settings were reestablished for normal cruise. The same procedure was used for grading Part B (1500-foot straight glide). A minimum of 1700 r.p.m. was required when clearing the engine during a glide.

Differences in practice for Control and Transfer Groups on the three dependent measures were significant ($p < .001$). This exercise is an excellent example of a situation in which equal amounts of Link training have a greater benefit than a similar training period in the air. All TERs were greater than 1.00, as shown in Exhibit 10, indicating that one trial in the trainer was equal to more than one trial in the aircraft in all cases.

Exercise 10. Climbing and gliding turns. The instructions for this exercise included a complete explanation of how, in a climb or glide, the torque effect varies according to the direction of the turn. These effects were then translated in terms of control application.

For Part A (1500-foot climbing turns), the subject's first task was to establish a straight climb using correct power settings. Then, when airspeed was slowed to 120 m.p.h., the bank was established and held until altitude was within 100 feet of the desired altitude. The trial ended when normal cruise power settings were reestablished in straight and level flight.

Exhibit 10. Summary of results for Exercise 9: Straight climbs and glides.

Item	A	B	Sum
	ERRORS		
Link Trainer (T)	17	39	56
SNJ Aircraft (T)	24	50	74
SNJ Aircraft (C)	60	166	226
Saving in Aircraft	36	116	152
Percent Transfer	60	70	67
Transfer Effectiveness	2.12	2.97	2.71
	TIME		
Link Trainer (T)	89	146	235
SNJ Aircraft (T)	78	125	203
SNJ Aircraft (C)	204	304	508
Saving in Aircraft	126	179	305
Percent Transfer	62	59	60
Transfer Effectiveness	1.42	1.23	1.30
	TRIALS		
Link Trainer (T)	20	32	52
SNJ Aircraft (T)	19	30	49
SNJ Aircraft (C)	54	74	128
Saving in Aircraft	35	44	79
Percent Transfer	65	59	62
Transfer Effectiveness	1.75	1.38	1.52

Additional instruction was given before the first trial on Part B of the exercise, 1500-foot gliding turns. The subject was reminded of the torque effect in relation to power changes and of standard procedures when entering or recovering from a glide. The maneuver was started by setting up a glide, and, as soon as the airspeed was slowed to 100 m.p.h., the gliding turn attitude was established. The subject was required to maintain the bank and airspeed until the aircraft was within 250 feet of the desired altitude. The accuracy of the leveling off procedure was graded when cruising power was reestablished.

Absolute savings in time, trials, and errors represent differences significant at the .01 level. Although positive transfer was high in both parts of the exercise, TERs calculated for Part A were exceptionally high (8.56, 1.70, and 3.40 for errors, time, and trials, respectively), as shown in Exhibit 11.

Exhibit 11. Summary of results for Exercise 10: Climbing and gliding turns.

Item	A	B	Sum
	ERRORS		
Link Trainer (T)	9	14	23
SNJ Aircraft (T)	22	41	63
SNJ Aircraft (C)	99	67	166
Saving in Aircraft	77	26	103
Percent Transfer	78	39	62
Transfer Effectiveness	8.56	1.86	4.48
	TIME		
Link Trainer (T)	90	77	167
SNJ Aircraft (T)	77	142	219
SNJ Aircraft (C)	230	191	421
Saving in Aircraft	153	49	202
Percent Transfer	67	26	48
Transfer Effectiveness	1.70	0.64	1.21
	TRIALS		
Link Trainer (T)	15	15	30
SNJ Aircraft (T)	20	33	53
SNJ Aircraft (C)	71	58	129
Saving in Aircraft	51	25	76
Percent Transfer	72	43	59
Transfer Effectiveness	3.40	1.67	2.53

Exercise 11. Stalls. The general instructions for the entire exercise included a short explanation of what occurs when an airplane stalls, what causes it to stall, how to recover from a stall with minimum loss of altitude, and the additional torque effect involved when entering or recovering from a stall. For the Transfer Group, Parts A, B, C, and D were performed in the Link and then in the air, E and F in the Link and then in the air, and finally G in the Link and then in the air.

Part A was a normal stall, power on. Recovery was to start before either wing started down but not before a definite break in the control pressure was felt.

Part B was a normal stall, power off. The entry to this part of the exercise was the same as the entry to a normal glide. The recovery was to be started at the first sign of the stall. The first sign or cue was the shuddering of the airplane that occurs just before an abrupt drop of the wing and nose.

Part C was a partial stall, power on. The performance of this stall was the same as for the normal stall, power on, except that the subject was required to recover before the stall actually occurred but not before an airspeed of 65 m.p.h. was attained.

Part D was a partial stall, power off. The performance of this stall was similar to that of the normal stall, power off, with the exception that the recovery was initiated before the stall actually occurred but not before an airspeed of 75 m.p.h. was attained.

Parts E and F were normal stalls from slow-flight climbing turns and slow-flight gliding turns, respectively. On consecutive trials direction of turn was alternated.

Part G of this exercise was a landing procedure stall. Before either group attempted this maneuver, they were required to memorize all procedures involved. In performing the maneuver, after all procedural items had been completed, the subject made a 90-degree turn onto a simulated final approach, lowered full flaps and then held a 90 m.p.h. gliding airspeed for a full-flap final approach until the instructor told him to stall the airplane.

A complete summary of results for Exercise 11 is given in Exhibit 12. When differences in time, trials, and errors were summed across all parts of the exercises, all overall differences were significant at the .001 level.

Exercise 12. Entry to the traffic pattern. The instructions for this exercise were given to the subject while on the ground and were not recorded as a part of exercise time. The subject was briefed on the procedures involved in making a standard entry to the traffic pattern. To clarify the pattern procedures, the instructor diagrammed them on a blackboard. When the subject felt he understood the exercise, he practiced by calling out all cockpit and pattern procedures in correct sequence as he drew the proper entries for various wind directions on the blackboard. When three correct trials were made on procedure, the subject proceeded to the aircraft or the Link.

The exercise was started at a position at least two miles from the airport and was completed at the end of the downwind leg. The procedure on this exercise required the subject to complete the first four items before the 45-degree approach leg was started. The approach leg itself was to be entered at least two miles out and was to be in line with the center of the airport or within such boundaries that it would intersect the downwind leg somewhere in the first

Exhibit 12. Summary of results for Exercise 11: Stalls.

Item	A	B	C	D	E	F	G	Sum
				ERRORS				
Link Trainer (T)	5	7	2	0	10	4	27	55
SNJ Aircraft (T)	17	10	6	6	16	14	10	79
SNJ Aircraft (C)	87	55	21	10	23	20	23	239
Saving in Aircraft	70	45	15	4	7	6	13	160
Percent Transfer	80	82	71	40	30	30	57	67
Transfer Effectiveness	14.00	6.43	7.50	[a]	0.70	1.50	0.48	2.91
				TIME				
Link Trainer (T)	34	43	17	18	57	28	121	318
SNJ Aircraft (T)	24	18	11	24	32	54	92	255
SNJ Aircraft (C)	84	110	37	32	52	45	135	495
Saving in Aircraft	60	92	26	8	20	−9	43	240
Percent Transfer	71	84	70	25	38	−20	32	48
Transfer Effectiveness	1.76	2.14	1.53	0.44	0.35	−0.32	0.36	0.75
				TRIALS				
Link Trainer (T)	11	13	8	4	13	8	21	78
SNJ Aircraft (T)	24	6	7	10	13	13	12	85
SNJ Aircraft (C)	62	46	30	16	22	17	20	213
Saving in Aircraft	38	40	23	6	9	4	8	128
Percent Transfer	61	87	77	38	41	24	40	60
Transfer Effectiveness	3.45	3.54	2.88	1.50	0.69	0.50	0.38	1.64

[a] Because the divisor is zero, a TER cannot be calculated.

third. In addition, it was required that 800 feet of altitude and correct power settings be established before the aircraft was within one mile of the downwind leg.

When the subjects of either group attempted the exercise in the aircraft, the first trial was a scored trial and not a demonstration. If excessive errors, denoting a lack of orientation, were made on this first trial, the instructor gave a demonstration trial using the same wind direction as the subject had used. The subject then attempted the third trial, using the same setting, and continued using this setting until a successful trial was scored. After a successful trial, a new wind direction was used. Criterion performance required that three consecutive successful trials be made, each using a different wind direction.

The Transfer Group, when attempting the exercise in the trainer, required additional use of the blackboard. A drawing of the airport was on the board, and the subject's task was to fly a correct traffic entry in relation to the drawing. He received his cues of direction and position from a line drawn by the instructor. This chalk line was supposed to simulate the progress of the airplane over the ground. The line was drawn at a steady rate and in the direction that the Link was headed. As soon as the subject started a turn, the instructor stopped the line until the turn was completed and then continued the line in the new direction. While the subject was flying the pattern, he was required to call out all cockpit procedures so that the instructor could grade the entire exercise. As the instructor drew the flight-path line, he attempted to make the student account for such items as drift and ground speed in relation to an imaginary wind.

Transfer remained high on this exercise with differences in time, trials, and errors between the Transfer and Control Groups significant at the .05 level. Although transfer of time was 74 percent, the corresponding TER was 0.58, indicating that roughly two hours in the Link equaled one hour in the air on this type of task. Summarized results for Exercise 12 are included in Exhibit 5.

Exercise 13. Flying the traffic pattern. As in Exercise 12, the subjects were first drilled on all procedures involved in flying the traffic pattern, including cockpit items. The drill was accomplished by verbalizing all items of cockpit and pattern procedure while drawing the traffic pattern on a blackboard. The blackboard upon which the subject drew his pattern had a diagram of the airport's runways on it. Before the subject attempted the exercise in either the Link or the aircraft, he was required to make three satisfactory simulated trials on the blackboard.

When the exercise was performed in the Link, the subject simulated all phases of flying the pattern, including takeoffs and landings. The first trial in the aircraft for both groups was an attempted trial by the subject; the second was either a student trial or a demonstration trial if the instructor deemed it necessary.

For each trial on this exercise, the subject made the takeoff and landing with instructor assistance. When the final turn to the runway was made, it had to be so planned that there was no overshooting the turn or leveling the wings before the turn was completed.

Differences in errors and exercise time were significant at the .001 level and differences in trials at the .01 level. TERs ranged from 1.18 on trials to 1.93 on exercise time (Exhibit 5).

Exercises 12 and 13 were the only two representatives of the ground-referenced exercise category performed in flight. Because transfer was somewhat greater on Exercise 13 than on the previous exercise, a learning effect might have existed. That is, subjects might have learned to discriminate those aspects of the Link task essential to in-the-air flight and, thus, benefited more from Link practice on the second ground-referenced flight task.

Discussion

Use of the SNJ trainer to teach contact flight tasks resulted in high positive transfer to performance in the aircraft on all three types of exercises used. A summary of transfer results for procedural exercises, contact airwork exercises, and ground-referenced flight exercises is included in Exhibit 5. Interestingly, even the crude extra-cockpit visual cue used in Exercise 12 (a chalk line on a blackboard) did not eliminate positive transfer effects. However, not all items in each task resulted in equal amounts of transfer. For example, Link training on coordination of aileron and rudder produced little transfer to the air when originally introduced in Exercise 5, and this low level of transfer probably contributed to the low transfer measured on Part A of Exercise 7, holding straight and level flight for two minutes, because the task required that heading corrections be made with coordinated aileron and rudder movements. Overall, the high level of transfer suggests potentially large savings in flight time to teach many contact flight tasks using an appropriate ground trainer.

Kinesthetic cues. One unexpected finding in this study, negative transfer on 180-degree level turns following positive transfer on 90-degree level turns, might be related to the fidelity of kinesthetic cues in the trainer. The similarity of the two turns is obvious, and one would predict a beneficial practice effect from one to the other. On the first task, 90-degree level turns, Link training proved to be beneficial with a definite saving in air time. However, subsequent Link practice on an almost identical task, 180-degree level turns, seemed to interfere with performance in the air.

A more detailed look at error scores on all turns in Exercise 8 reveals that errors in the aircraft for the Transfer Group were primarily in two areas—holding original altitude and holding the correct degree of bank. Correct bank angle varied for the four turns with 30 degrees on 90-degree and 180-degree level turns, 15 degrees on 180-degree turns in slow flight, and 45 degrees on 360-degree steep turns. The difficulty of holding altitude is directly related to the degree of bank required; increasing bank angle increases the forces on the plane and with it the difficulty of maintaining altitude. Exhibit 13 summarizes the errors on holding original altitude on all turns in Exercise 8. As might be predicted, the fewest altitude errors were made on Part C, 180-degree slow-flight turns, where only a 15-degree bank angle was required. During Link training on the other three turns, the ability to hold altitude appeared to improve. However, subsequent error scores in the air indicate that Link training was not totally effective and did not substantially reduce this type of error. Altitude errors accounted for about 60 percent of all errors on normal flight turns made by the Transfer Group in the air. Possibly the need for a large amount of in-the-air training to learn this skill was a result of differences in kinesthetic cues or control pressures experienced in the trainer over those experienced in the aircraft.

Exhibit 13. Errors in holding original altitude in Exercise 8.

Training Device	A	B	C	D	Sum
Link Trainer (T)	23	9	3	0	35
SNJ Aircraft (T)	27	44	1	27	99
SNJ Aircraft (C)	59	26	7	54	146

When all performance items for each part were summed, negative transfer was indicated in Part B only. This was probably a result of slight fluctuations in level of performance on the other items and not an indication that something unique occurred with 180-degree turns.

Distribution of practice. Results for procedural items used in the experiment indicate a definite training advantage of ground trainers over the actual aircraft. Although certain items, such as starting the aircraft, cannot be repeated over and over in the aircraft because of potential damage to equipment, often no such danger exists in the ground trainer. Thus, massed practice is possible and, according to the results of this study, is desirable to teach certain procedural items.

Measuring transfer. How to measure transfer of training meaningfully is a continuing research argument. Results of this study strongly support the need for transfer measures that use amount of prior practice as a factor in calculating transfer. When only differences in air practice are used, positive transfer may be indicated when excessive amounts of practice were required on an original task. Indeed this was the case in Exercise 5, effect of controls. Obviously, the use of ground training in such a situation would not be cost effective. Transfer effectiveness measures permit cost-payoff tradeoffs in the use of ground-training devices.

EXPERIMENT II. INSTRUMENT FLIGHT

In many respects the instrument flight experiment was similar to the contact flight experiment. Only those details in which the two studies differed will be mentioned.

Method

Equipment. The equipment was essentially the same as in Experiment I except that, when instrument flying was taught, the cockpit windshield in the trainer or aircraft was covered with an inner liner of amber plexiglass, and students wore blue goggles.

Subjects. Twelve subjects were used in this experiment. They included college juniors, graduate students, and two full-time faculty members. The selection of subjects was based on the following qualifications: (1) no previous instrument flying experience, either simulated or actual; (2) previous contact flying experience of 36 to 40 hours; (3) a Private Pilot rating obtained by completing the prescribed curriculum of the Institute of Aviation at the University of Illinois, Urbana-Champaign; (4) an academic schedule that would not interfere with a regular flight schedule; and (5) assurance that the subject would be able to complete his part of the experiment.

Experimental groups. Assignment of students to either the Transfer Group or Control Group was based on ability to meet a prescribed flight schedule of four one-hour periods per week distributed over three days. No student was scheduled for more than two flights on any one day. Furthermore, if a student had two flights during one day, the flights were separated by at least one hour.

Procedure. As in the contact flight experiment, several training procedures were used to enhance training effectiveness. Training procedures common to both the contact and instrument flight experiments were:

1. A clear definition of the task to be learned for the instructor and the student.
2. An attempt to keep each increment of the task as simple as possible.
3. Satisfactory two-way communication between student and instructor to avoid learning without understanding the task.
4. Immediate knowledge of results for both the instructor and the subject upon the completion of a trial. This knowledge

was obtained from the performance record sheet which was broken down into the essential components of the maneuver.

In the present study, several additional techniques were used to solve the problem of training subjects to a relatively high level of instrument flying proficiency in a relatively few hours of practice. These special methods are described as follows:

1. All subjects required to read specified material related to the general task of learning the skill of instrument flying.
2. Ground and air familiarization with the aircraft prior to starting the first exercise.
3. "Intellectualization" of a maneuver by components prior to practice on the maneuver in the Link or the aircraft.
4. Use of a developmental syllabus in which the learning of each succeeding task was facilitated by proficiency in a preceding task.

The material learned consisted of six exercises. They were:

1. *Use of the artificial horizon.* The maneuvers included in this exercise were straight and level flight, straight climbs and descents, and 180-degree turns. These maneuvers were performed with all flight instruments covered except the artificial horizon.
2. *Use of the full panel.* The maneuvers included in this exercise were the same as those in Exercise 1, except that greater precision was required. The maneuvers were performed with all flight instruments uncovered, but they were not performed according to any specified rates.
3. *Standard rate climbs, descents, and level turns.* The maneuvers in this exercise were essentially the same as those in the first two exercises, except that they were performed at standard rates. The climbs and descents were made at 500 feet per minute and the turns at three degrees per second.
4. *Slow flight.* The maneuvers in this exercise included straight and level slow flight and standard rate slow-flight turns of 45, 90, and 180 degrees.
5. *Rated climbing and descending turns.* The maneuvers in this exercise included a 360-degree standard rate climbing turn at a vertical speed of 500 feet per minute and a 360-degree standard rate descending turn at a vertical speed of 500 feet per minute.

6. *Steep turns; power-on and power-off stalls.* The maneuvers in this exercise included a steep turn made in the normal manner, a normal power-on stall performed straight ahead from cruising flight, and a power-off stall from a gliding turn.

The exercises were selected from maneuvers included in most instrument training syllabi. Performance criteria for the components of the first exercise were determined by recording the performances of two currently rated instrument pilots with several hundred hours of recent experience in the SNJ aircraft. The performance criteria for the other exercises were established in relation to performance tolerances generally acceptable in both civil and military aviation. These criteria were further checked on two preexperimental subjects to make certain that they could be achieved with a reasonable amount of practice.

As in the contact study, all exercises were performed under smooth air conditions. In the Link, the less difficult parts of an exercise were performed under conditions of simulated rough air. This condition was imposed on the assumption that more effective use of the trainer was thereby attained. This assumption was based upon the experimenters' experience in previous studies concerning utilization of synthetic flight trainers.

Three instructors participated in the experiment. Each was checked on his ability to score performance on a record sheet by having him score another instructor's performance on maneuvers in which certain predetermined errors were made. All instructors were required to practice scoring until they were able to record without missing errors. No assignment of any subject to a particular instructor was made, and all students flew with all three instructors.

During the course of the experiment, an unavoidable interruption of approximately 30 days occurred in the training of the Transfer Group. (The interruption was the result of a University vacation and the installation of new equipment in the trainer. The new equipment was not related to this study.) When the transfer students resumed their training, it was considered desirable for them to review, both in the Link and in the aircraft, the last exercise they had completed in the aircraft. This extra time was not included as part of the experimental time.

Results

Data from the instrument flight experiment were analyzed using the same transfer measures employed in the contact flight experiment, percent transfer and transfer effectiveness. The results of Experiment II are summarized in Exhibit 14. Given are the number of errors made, the number of trials taken, and the total amount of time required by each group to learn to perform all six exercises at the criterion level of proficiency in the SNJ aircraft. The exhibit also shows the errors, trials, and times required by the Transfer Group to learn the exercises in the Link trainer. The three errorless trials and the time consumed by them are not included in the values presented in any exhibit.

Exhibit 14. Summary of transfer of training in errors, time, and trials for the instrument flight experiment.

Item	Errors	Time	Trials
Link Trainer (T)	879	2178	584
SNJ Aircraft (T)	492	1187	286
SNJ Aircraft (C)	1158	2494	687
Saving in Aircraft	666	1307	401
Percent Transfer	58	53	45
Transfer Effectiveness	0.76	0.60	0.69

Transfer of training from the SNJ Link trainer to the SNJ aircraft resulted in savings of 58 percent in errors (TER = 0.76), 53 percent in time devoted to practice on the exercises (TER = 0.60), and 58 percent in trials required to learn to perform the exercises at criterion proficiency in the airplane (TER = 0.69). The students in the Transfer Group who first learned to perform the maneuvers in the Link trainer required slightly less than half as much training in the airplane as the students in the Control Group.

The differences between the amount of practice required in the aircraft by the two groups were statistically significant at the .01 level for time and errors and at the .001 level for trials. As in the case of the contact flight training experiment, there was no overlap whatever between the members of the two groups. The poorest student in the Transfer Group learned faster than the best student in the Control Group as indicated by each of the three measures.

The six exercises learned by the subjects in this experiment represent a seven-hour (actually 6.93-hour) instrument flight syllabus, the average time required by the members of the Control Group to learn the six exercises. As in the case of the contact flight training experiment, this time excludes flight time required to perform the errorless criterion trials and flight time spent by the instructor in taking off, climbing to flight altitude, maneuvering into position for successive trials, giving verbal instructions between trials, descending, landing, and returning to the parking area at the end of each flight.

The savings attributable to the use of the Link trainer in this experiment were relatively less than those obtained in the contact flight training experiment when compared with all types of exercises taught in that experiment. However, when compared only with the flight exercises taught in that experiment, the savings were more nearly comparable. For example, the overall saving in time in this experiment was 53 percent as compared with an overall saving in time of 56 percent for the contact flight training experiment when the four procedural exercises performed on the ground are excluded. Corresponding values for the other two measures were 58 percent as compared with 70 percent in errors and 58 percent as compared with 60 percent in trials. Although the procedural tasks performed only on the ground yielded a very high percentage of transfer, their TERs were comparable to those of the flight maneuvers.

Exhibit 15 summarizes individual results for each exercise. Using the percent transfer measure, the magnitude of saving attributable to the use of the Link trainer is associated, in general, with the difficulty of the maneuver, the greater savings resulting for the maneuvers generally considered to be the more difficult. For example, the exercises showing the highest percent transfer were Exercise 5, rated climbing and descending turns, and Exercise 6, steep turns and stalls. These were the most difficult maneuvers employed in the experiment.

Exhibit 15. Percent transfer (PT) and transfer effectiveness ratio (TER) in errors, time, and trials for each exercise.

Exercise	Errors		Time		Trials	
	PT	TER	PT	TER	PT	TER
1. Use of Artificial Horizon	60	1.18	53	0.80	58	0.86
2. Use of Full Panel	23	0.27	44	0.63	44	0.60
3. Standard Rate Climbs, Descents, and Level Turns	47	0.43	47	0.43	57	0.47
4. Slow Flight	43	0.95	50	0.98	48	1.07
5. Rated Climbing and Descending Turns	71	0.95	63	0.65	69	0.81
6. Steep Turns; Power-On and Power-Off Stalls	69	0.68	59	0.46	70	0.63
ALL EXERCISES COMBINED	58	0.75	53	0.60	58	0.69

The smallest savings were obtained for Exercise 2. The maneuvers learned in this exercise were identical to those in Exercise 1 except that much greater precision was required in their execution. Although this might make Exercise 2 appear to be more difficult than Exercise 1, it was actually less difficult in terms of errors, time, and trials required to reach criterion, because the subjects had already received considerable practice on the maneuvers while learning Exercise 1. In other words, there was considerable positive transfer from Exercise 1 to Exercise 2. This was reflected in the lower scores by the Control Group on Exercise 2 than on Exercise 1, even though greater precision was required in the second exercise. Although there was positive transfer between successive exercises, the effect was probably not so great in any other case as it was between Exercises 1 and 2.

Interestingly, the exercises yielding the highest transfer effectiveness differed from those resulting in the highest percent transfer scores. Exercise 1, use of the artificial horizon, and Exercise 4, slow flight, produced the most efficient transfer when number of trials on the trainer was considered.

The errors made by the Transfer and Control Groups on each of the 212 scoring items for the six exercises are presented in Appendix B. Each of the items is defined operationally in terms of what the student had to do, and the criterion of correct performance on each item is given.

On the following pages more detailed results of the instrument flight experiment are presented. Each exercise is dealt with separately.

Exercise 1. Use of the artificial horizon. The procedure followed in this exercise was designed to help the subject make the transition from contact to instrument flying as easily as possible. Prior to the initial trial on this exercise, the subject had to "intellectualize" his task. This meant the ability to verbalize all maneuver components, tolerances, cues, and responses needed for successful performance of the exercise. This requirement was common to all exercises in this experiment.

For the next 15 to 20 minutes the subject practiced the exercise maneuvers under contact flight conditions with the instructor pointing out the cues necessary for the successful performance of each maneuver. This was done in both the trainer and the aircraft. The basic flight maneuvers included in this exercise were straight and level flight, 180-degree level turns, and straight climbs and descents.

Following contact flight practice on the maneuvers, all flight instruments except the artificial horizon were covered, and the subject put on blue goggles, eliminating all visual cues from outside the cockpit. With the subject observing, the instructor then demonstrated how the same cues used for contact flying could be provided by the artificial horizon. The subject was then allowed to start his practice trials.

Differences between the Transfer and Control Groups on each of the three dependent variables were significant at the .05 level. Overall percent transfer ranged from 53 to 60 percent, whereas transfer effectiveness ranged from 0.80 to 1.18 (Exhibit 16).

Exhibit 16. Summary of results for Exercise 1: Use of the artificial horizon.

Item	A	B	C	D	Sum
			ERRORS		
Link Trainer (T)	13	33	61	40	147
SNJ Aircraft (T)	8	19	63	27	117
SNJ Aircraft (C)	25	52	151	62	290
Saving in Aircraft	17	33	88	35	173
Percent Transfer	68	63	58	56	60
Transfer Effectiveness	1.31	1.00	1.44	0.88	1.18
			TIME		
Link Trainer (T)	81	49	120	79	329
SNJ Aircraft (T)	48	36	100	53	237
SNJ Aircraft (C)	71	67	235	128	501
Saving in Aircraft	23	31	135	75	264
Percent Transfer	32	46	57	59	53
Transfer Effectiveness	0.28	0.63	1.13	0.95	0.80
			TRIALS		
Link Trainer (T)	20	27	31	20	98
SNJ Aircraft (T)	10	21	20	10	61
SNJ Aircraft (C)	20	38	61	26	145
Saving in Aircraft	10	17	41	16	84
Percent Transfer	50	45	67	62	58
Transfer Effectiveness	0.50	0.63	1.32	0.80	0.86

Exercise 2. Use of the full panel. The maneuvers in this exercise were the same as those in the first exercise, but they had to be executed with greater precision. Completion of Exercise 1 provided the student with a basic pattern for instrument flying. In his successful

performance the student had demonstrated to himself that he could fly the airplane within reasonable tolerances with the artificial horizon as his only visible flight attitude reference. The fact that use of other flight instruments would make instrument flying easier and performing within smaller tolerances possible was then explained. To make the complete flight easier and its performance more exact, the artificial horizon was used to establish and maintain attitudes; the other flight instruments indicated whether or not the attitude was correct. Furthermore, when an adjustment was required, the additional instruments showed the amount and direction of the adjustment required.

Before the first practice trial on this exercise, the instructor thoroughly briefed each student on the functions of the instruments other than the artificial horizon and the interpretation and utilization of the information provided by them. The importance of small corrections was stressed. Each student was asked to verbalize the correct procedures for entering and leveling off from a climb or glide.

The only significant difference between the Transfer and Control Groups was the difference in overall exercise time ($p < .05$). Percent transfer was 23, 44, and 44 percent for errors, time, and trials, respectively, and transfer effectiveness was 0.27, 0.63, and 0.60, respectively (Exhibit 17). Part C (straight climbs) resulted in negative transfer of errors. In view of the moderate positive transfer measured on time and trials for Part C, the low negative transfer could easily be a chance effect.

Exercise 3. Standard rate climbs, descents, and level turns. The tolerances established for the maneuver components of this exercise were the same as those in Exercise 2. The task was identical except for the additional requirement that maneuvers be performed at a certain rate.

Correct performance on Part A (straight and level flight for two minutes) simply required the subject to tell the instructor when he started a two-minute trial and when it was completed. A five-second tolerance was established.

Part B was a 180-degree standard rate turn. Prior to practice on the exercise the student was thoroughly briefed on the correct bank to use for a standard rate turn, how to use the rate-of-turn indicator to determine whether or not the correct attitude was being maintained on the artificial horizon, and how to check the rate of turn being made good every 15 seconds on the directional gyro.

Exhibit 17. Summary of results for Exercise 2: Use of the full panel.

Item	A	B	C	D	Sum
			ERRORS		
Link Trainer (T)	7	24	36	11	78
SNJ Aircraft (T)	3	16	44	8	71
SNJ Aircraft (C)	16	23	34	19	92
Saving in Aircraft	13	7	−10	11	21
Percent Transfer	81	30	−29	58	23
Transfer Effectiveness	1.86	0.29	−0.28	1.00	0.27
			TIME		
Link Trainer (T)	44	67	89	63	263
SNJ Aircraft (T)	19	41	96	55	211
SNJ Aircraft (C)	68	66	151	91	376
Saving in Aircraft	49	25	55	36	165
Percent Transfer	72	38	36	40	44
Transfer Effectiveness	1.11	0.37	0.62	0.57	0.63
			TRIALS		
Link Trainer (T)	10	23	19	8	60
SNJ Aircraft (T)	4	14	21	7	46
SNJ Aircraft (C)	20	21	28	13	82
Saving in Aircraft	16	7	7	6	36
Percent Transfer	80	33	25	46	44
Transfer Effectiveness	1.60	0.30	0.37	0.75	0.60

Performance on Parts C and D required the subject to establish and maintain a 500-foot-per-minute vertical speed. Prior to performance on these parts of the exercise the subject was briefed on the use of the vertical-speed indicator in establishing an attitude on the artificial horizon and the use of the altimeter in checking the rate of climb each 15 seconds. Use of the throttle in controlling vertical speed was stressed.

Practice differences in time and trials were significant at the .01 level and differences in errors at the .05 level. Percent transfer and transfer effectiveness were essentially identical for all dependent variables. Percent transfer was 47, 47, and 57 percent for errors, time, and trials, respectively; transfer effectiveness was 0.43, 0.43, and 0.47, respectively (Exhibit 18).

Exercise 4. Slow flight. This entire exercise was oriented about the problem of slow flight. The student was required to learn how

Exhibit 18. Summary of results for Exercise 3: Standard rate climbs, descents, and level turns.

Items	A	B	C	D	Sum
			ERRORS		
Link Trainer (T)	5	97	52	67	221
SNJ Aircraft (T)	1	41	31	34	107
SNJ Aircraft (C)	5	67	77	52	201
Saving in Aircraft	4	26	46	18	94
Percent Transfer	80	39	60	35	47
Transfer Effectiveness	0.80	0.27	0.88	0.27	0.43
			TIME		
Link Trainer (T)	37	258	179	201	675
SNJ Aircraft (T)	8	73	71	167	319
SNJ Aircraft (C)	22	139	273	172	606
Saving in Aircraft	14	66	202	5	287
Percent Transfer	64	47	74	3	47
Transfer Effectiveness	0.38	0.26	1.13	0.02	0.43
			TRIALS		
Link Trainer (T)	6	90	37	40	173
SNJ Aircraft (T)	1	26	12	23	62
SNJ Aircraft (C)	3	47	57	37	144
Saving in Aircraft	2	21	45	14	82
Percent Transfer	67	45	79	38	57
Transfer Effectiveness	0.33	0.23	1.22	0.35	0.47

to enter, maintain, and recover from straight and level slow flight and from standard rate, slow-flight turns of 45, 90, and 180 degrees. A considerable knowledge of procedures was required in the performance of this exercise; hence the subject's ability to "intellectualize" the exercise was stressed. This included the ability to verbalize all power settings, the changing trim requirements with airspeed changes, the effect of torque as a result of power changes, and the differential effect of torque upon entry and recovery from a turn to the left as compared to a turn to the right. Procedures for using the throttle to maintain altitude and the elevator to maintain airspeed were also verbalized.

No overall practice differences were significant. However, the difference in errors of the Transfer and Control Groups on Part C was significant ($p < .05$). Considerable fluctuation in both percent transfer and transfer effectiveness occurred among the various exer-

Exhibit 19. Summary of results for Exercise 4: Slow flight.

Item	A	B	C	D	Sum
			ERRORS		
Link Trainer (T)	13	17	5	7	42
SNJ Aircraft (T)	21	21	4	8	54
SNJ Aircraft (C)	32	18	33	11	94
Saving in Aircraft	11	−3	29	3	40
Percent Transfer	34	−17	88	27	43
Transfer Effectiveness	0.85	−0.18	5.80	0.43	0.95
			TIME		
Link Trainer (T)	39	54	28	15	136
SNJ Aircraft (T)	54	28	20	33	135
SNJ Aircraft (C)	130	41	74	23	268
Saving in Aircraft	76	13	54	−10	133
Percent Transfer	58	32	73	−43	50
Transfer Effectiveness	1.95	0.24	1.93	−0.67	0.98
			TRIALS		
Link Trainer (T)	10	20	7	4	41
SNJ Aircraft (T)	10	17	6	15	48
SNJ Aircraft (C)	23	22	37	10	92
Saving in Aircraft	13	5	31	−5	44
Percent Transfer	57	23	84	−50	48
Transfer Effectiveness	1.30	0.25	4.43	−1.25	1.07

cise parts. Percent transfer ranged from −50 percent to 88 percent; transfer effectiveness ranged from −1.25 to 5.80 (Exhibit 19).

Exercise 5. Rated climbing and descending turns. Prior to the first practice on the exercise, the subject was required to memorize the correct sequence of altitudes and headings through which the aircraft should pass at 15-second intervals during 360-degree climbing and descending turns to the right and to the left. Performance was recorded every 30 seconds in terms of these altitudes and headings and in terms of airspeed and coordination which had been maintained during the period.

Before the subject began a trial, the aircraft was trimmed by the instructor to maintain straight and level flight at 120 m.p.h. The climbs and descents were started from some exact thousand-foot altitude and with a heading of North. A trial was started just as the sweep-second hand of the clock passed through the 12 o'clock position. Alternate trials were made to the right and to the left for both climbing and descending turns. The subject increased or decreased power as the required pitch and bank attitudes were established.

The difference in exercise time for the Transfer and Control Groups was significant at the .001 level. Error and trial differences were significant at the .01 level. Percent transfer and transfer effectiveness were approximately the same for each dependent measure. Amount of transfer increased from Part A to Part B (Exhibit 20).

Exhibit 20. Summary of results for Exercise 5: Rated climbing and descending turns.

Item	A	B	Sum
	ERRORS		
Link Trainer (T)	187	87	274
SNJ Aircraft (T)	75	32	107
SNJ Aircraft (C)	121	245	366
Saving in Aircraft	46	213	259
Percent Transfer	38	87	71
Transfer Effectiveness	0.25	2.45	0.95
	TIME		
Link Trainer (T)	381	142	523
SNJ Aircraft (T)	132	71	203
SNJ Aircraft (C)	209	336	545
Saving in Aircraft	77	265	342
Percent Transfer	37	79	63
Transfer Effectiveness	0.20	1.87	0.65
	TRIALS		
Link Trainer (T)	89	30	119
SNJ Aircraft (T)	31	13	44
SNJ Aircraft (C)	53	87	140
Saving in Aircraft	22	74	96
Percent Transfer	42	85	69
Transfer Effectiveness	0.25	2.47	0.81

Exercise 6. Steep turns; power-on and power-off stalls. This exercise included three separate maneuvers. On Part A, the steep turn, the student was thoroughly briefed on the method of entering the turn, the correct bank, important cues to determine an adequate response for altitude control, and approximately where in the turn

to start the recovery. Power adjustments were not required in this maneuver.

Part B was a normal power-on stall performed straight ahead from cruising flight. Correct performance of the task required that the stall attitude be established before airspeed dropped below 120 m.p.h. On recovery, the aircraft was to be in level flight attitude by the time the airspeed was 100 m.p.h.

Part C of the exercise was a power-off stall from a gliding turn. Correct procedure required that the subject maintain altitude and heading while closing the throttle and allowing the airspeed to drop to 120 m.p.h. A gliding turn was then established following which the pitch of the aircraft was to be increased to the three-point attitude. On recovery from the stall, the aircraft was to be in level flight at the time the airspeed was 100 m.p.h.

The only significant differences between the Transfer and Control Groups were on overall exercise time and number of trials for Part A ($p < .05$). Results for Parts A and B again emphasize the need for transfer measures to take into account practice on the prior task. Although percent transfer in errors, time, and trials on Part A was 80, 77, and 80 percent, respectively, and on Part B was 68, 56, and 71 percent, respectively, transfer effectiveness on Part A was 0.49, 0.53, and 0.44, respectively, and on Part B was 2.00, 0.50, and 2.00, respectively (Exhibit 21).

Discussion

The high level of positive transfer of ground training to instrument flight in the air was particularly encouraging in view of the unavoidable interruption in the training program. On all exercises an hour of training in the Link was equivalent to no less than a half-hour in the aircraft, and for slow-flight training an hour in the Link equaled an hour in the air.

Practice effects. The results of Exercise 5, rated climbing and descending turns, indicated that ground training was more effective for teaching descending turns after climbing turns were practiced. A detailed review of errors on both parts indicates that most errors on climbing turns in the Link were made in completing the correct number of degrees of turn and completing the correct number of feet of climb. Little difficulty was encountered in holding airspeed or coordinating aileron and rudder. Because the number of errors

Exhibit 21. Summary of results for Exercise 6:
Steep turns; power-on and power-off stalls.

Item	A	B	C	Sum
		ERRORS		
Link Trainer (T)	80	15	22	117
SNJ Aircraft (T)	10	14	12	36
SNJ Aircraft (C)	49	44	22	115
Saving in Aircraft	39	30	10	79
Percent Transfer	80	68	45	69
Transfer Effectiveness	0.49	2.00	0.45	0.68
		TIME		
Link Trainer (T)	137	66	49	252
SNJ Aircraft (T)	22	26	34	82
SNJ Aircraft (C)	94	59	45	198
Saving in Aircraft	72	33	11	116
Percent Transfer	77	56	24	59
Transfer Effectiveness	0.53	0.50	0.22	0.46
		TRIALS		
Link Trainer (T)	64	11	18	93
SNJ Aircraft (T)	7	9	9	25
SNJ Aircraft (C)	35	31	18	84
Saving in Aircraft	28	22	9	59
Percent Transfer	80	71	50	70
Transfer Effectiveness	0.44	2.00	0.50	0.63

in the Link on completing turns and climbs within limits was so great and the subsequent number of errors in the aircraft remained high, total errors for the Transfer Group on these two performance items were more than double the errors of the Control Group. However, Link performance on gliding turns improved so much that the Transfer Group's total errors on holding turns and glides was only half that of the Control Group. Evidently, prior practice in the Link on turns and climbs aided subsequent Link performance on turns and glides.

Dependent measures. In several instances amount of transfer on one dependent measure differed greatly from the transfer measured on another. For example, straight and level flight in Exercise 1 yielded TERs varying on time, trials, and errors from 0.28 to 1.31. In Exercise 2, TERs on straight climbs varied from −0.28 to 0.62. Obviously, slight differences on the three measures are not noteworthy. However, when large differences occur, it is important to determine whether the difference is a spurious effect or a real difference in transfer. Multiple dependent variables permit these comparisons. When only one dependent variable is used, random results are not so easily isolated.

CONCLUSIONS

At least three conclusions may be drawn from these studies: the measurement of transfer is a complex business; further research is needed; and something should be done about the publication lag.

The Anatomy of Transfer

The measurement of transfer is a complex business. If the relative effectiveness of transfer for various elements of any training curriculum is to be assessed, a research strategy must be developed to deal with the problem of transfer among the elements. More specifically, simulator training in one flight maneuver transfers not only to its airborne counterpart; it transfers to other similar maneuvers performed either in the simulator or in the airplane, as does training in the airplane itself. Furthermore, training on one aspect of the overall flight task, say verbal communication, may appear to transfer to another quite different aspect, say motor coordination, simply because the early mastery of the first may thereafter allow the student to concentrate more on the second.

The research strategy employed in these studies called for a student to master each element, or subtask, of the flight curriculum before proceeding to the next, either in the ground trainer or in the airplane. At the opposite extreme, the research strategy might have called for students in the Transfer Group to master the complete flight curriculum in the ground trainer before receiving any training in the aircraft. Had this strategy been employed, the results most certainly would have been quite different both in terms of cumulative transfer effectiveness and in terms of the relative transfer effectiveness for individual maneuvers and aspects of performance. Nevertheless, a great deal may be learned about the anatomy of transfer from a categorical analysis of the relative transfer effectiveness for the various types of flight tasks learned by the subjects in these experiments as summarized in Exhibit 22.

One consistent result was that instrument flight training in the ground-based trainer produced less transfer (TERs for errors, time, and trials were 0.76, 0.60, and 0.69, respectively) than did contact flight training (the corresponding TERs were 1.79, 0.88, and 1.13). This differential transfer might well have depended upon the impossibility of separating a pilot from his past experience.

As has already been noted, previous training either in the simulator or in the airplane may transfer directly among similar maneu-

Exhibit 22. Percent transfer (PT) and transfer effectiveness ratio (TER) for flight exercises by various task categories.

Task Category	Errors		Time		Trials	
	PT	TER	PT	TER	PT	TER
Contact versus Instrument						
Contact Flight	73	1.79	61	0.88	62	1.13
Instrument Flight	58	0.76	53	0.60	58	0.69
Procedural versus Psychomotor						
Primarily Procedural:						
Contact Exercises 1–4, 12	85	2.28	81	0.96	77	1.16
Primarily Psychomotor: Total	65	1.17	54	0.73	63	0.92
Contact Exercises 5–11, 13	70	1.69	56	0.86	65	1.13
Instrument Exercises 1–6	58	0.76	52	0.60	58	0.69
Time-Referenced versus Horizon-Referenced versus Ground-Referenced						
Time-Referenced:						
Instrument Exercises 3–5	59	0.73	54	0.57	59	1.44
Horizon-Referenced: Total	64	1.33	51	0.77	57	1.05
Contact Exercises 6–11	67	1.64	52	0.83	60	1.19
Instrument Exercises 1, 2, 6	55	0.80	48	0.65	48	0.71
Ground-Referenced:						
Contact Exercises 12–13	80	1.40	67	1.07	61	0.94

vers. Elements common to two tasks may be performed with little attention or effort while concentrating on the new elements of the second task. Although a student might require equal time to learn either task in isolation, having learned one in the airplane, with or without prior simulator training, less new learning is required to master the second in flight. Therefore, a smaller air-time saving is possible from learning the second maneuver in the simulator. Although less time might also be required to learn the new elements of the second maneuver in the simulator, transfer effectiveness usually turns out to be successively lower for the sequential learning of two or more similar tasks.

An example of the principle just stated is found in the results of the instrument flight experiment. In Exercises 1, 2, and 3 (Exhibits 16, 17, and 18) subjects performed the same flight maneuvers; but, in Exercise 1 only the artificial horizon was used, in Exercise 2 the full instrument panel was used, and in Exercise 3 the maneuvers were performed at standard rates. TERs for exercise times were 0.80, 0.63, and 0.43, respectively. The decreasing transfer effectiveness of the simulator is presumably attributable to the transfer of similar elements from one exercise to the next in the airplane, thereby leaving successively less to be transferred from the simulator. When a relatively dissimilar task, maneuvers in slow flight, was next introduced, transfer effectiveness returned to a higher level (the TER for exercise time was 0.98).

Because prior experience of both the Transfer and Control Groups, either in the simulator or in contact flight, must have transferred to instrument flight tasks in the air, the opportunity for transfer of specific simulator training on new instrument flight tasks to performance in flight was surely limited to some unknown degree. In a corollary manner, if instrument flight training were regularly given prior to contact flight training, it would be expected that relatively higher transfer effectiveness would be observed for the former because instrument and contact flight have much in common that can be learned originally in either context.

The identical-element theory of transfer, derived from psychological antiquity, is in general agreement with the fact that transfer effectiveness is a direct function of the similarity between new tasks learned in different training situations. Not all transfer phenomena can be attributed to similarity of elements, however. Prior training on one task may transfer to dissimilar tasks having no evidently common elements. For example, early mastery of communication with the control tower (not studied in these experiments) might well yield high transfer either to altitude control while flying the traffic pattern or to directional control while taking off, landing, and taxiing.

Transfer of the type represented by the examples just given evidently does not depend upon common task elements, but the basic psychological mechanism of transfer may be essentially the same. In either case a greater portion of the student's momentary attention capacity may be focused on new elements to be learned, thereby making their mastery more rapid.

Categorizing the training tasks led to several other conclusions. In general, procedural tasks, such as starting the airplane, resulted in more effective transfer (TERs in errors, time, and trials were 2.28, 0.96, and 1.16, respectively) than did psychomotor tasks, such as level turns (corresponding TERs were 1.17, 0.78, and 0.92). These results are consistent with related findings (Ornstein, Nichols, and Flexman, 1954). Apparently higher transfer occurs with procedural tasks than with psychomotor tasks because the former are less adversely affected by the imperfect simulation of such dynamic factors as physical motion, visual and kinesthetic cues, and control pressures.

This is not to say that effective transfer of procedural tasks requires less fidelity of simulation than psychomotor tasks. To the contrary, the conclusion must be that procedural fidelity is more critical than dynamic fidelity in simulator design. Lack of procedural fidelity results in the transfer of incorrect responses, thereby yielding negative transfer to the performance of correct procedures in flight. The 1-CA-2 Link, despite its relative simplicity and low cost, produced high transfer on procedural tasks because of its perfect procedural fidelity (with the exception of the inoperative wobble pump).

In addition, the procedural fidelity of the simulator, built from an actual cockpit of its flying counterpart, might very well have contributed to the high level of transfer on psychomotor tasks. Because the procedural aspects of these flight tasks could be well learned in the trainer, the student pilots in the Transfer Group were able to devote more time in the air to the psychomotor elements of flight maneuvers than students in the Control Group who were burdened with learning both the procedural and psychomotor elements concurrently.

There was little evidence of systematic differences in transfer effectiveness among time-referenced, horizon-referenced, and ground-referenced flight maneuvers. However, contact maneuvers referenced to the natural horizon were associated with higher transfer effectiveness than were instrument maneuvers referenced to the artificial horizon (TERs in errors, time, and trials, respectively, were 1.64, 0.83, and 1.19 compared with 0.80, 0.65, and 0.71). Furthermore, in terms of errors and exercise time, respectively, the highest transfer effectiveness was found for ground-referenced maneuvers (1.40 and 1.07) followed in descending order by horizon-referenced (1.33 and 0.77) and time-referenced tasks (0.73 and 0.57); in terms of trials this order was reversed (time-referenced, 1.44; horizon-referenced, 1.05; and ground-referenced, 0.94).

Transfer comparisons among the various types of tasks are inevitably confounded to some unknown extent by the fact that flight training tends to proceed from ground-referenced and natural-horizon-referenced maneuvers to artificial-horizon-referenced and time-referenced maneuvers. As previously discussed, opportunity for the transfer of new learning diminishes as a pilot masters more and more elements common to various tasks.

Future Research

Further research is needed. This perennial plea of the scientific community applies to the whole field of educational strategy, not only to the training of pilots. It is strikingly notable, however, that vast sums are invested in new and innovative pilot training devices and programs in the virtual absence of experiments providing quantitative estimates of relative transfer effectiveness attributable to the variable characteristics of the devices and training strategies employed.

Twenty Years' Perspective

Something should be done about the publication lag. Although 20 years is an unusually long hiatus, it has the redeeming virtue of allowing the investigators ample time to draw conclusions.

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Appendix A: Criteria and Error Tabulation for Each Performance Item, Contact Flight Experiment (Exercises 3–13)

Required Operation	Errors: Transfer Link	Errors: Transfer SNJ	Errors: Control SNJ	Criterion
Exercise 3: Starting Procedure				
1. Locks brakes	0	0	7	yes or no
2. Turns gas on RESERVE	1	0	6	yes or no
3. Checks prop in high pitch	2	3	4	yes or no
4. Opens throttle ½ inch	1	4	2	±¼ inch
5. Sets mixture RICH	1	2	2	yes or no
6. Checks carburetor heat COLD	5	2	15	yes or no
7. Wobbles until engine starts	1	1	5	yes or no
8. Primes two shots for warm engine, six for cold	0	0	4	yes or no
9. Turns battery switch ON	1	0	0	yes or no
10. Turns magnetos on BOTH	1	1	3	yes or no
11. Energizes for 12–15 seconds	2	0	3	yes or no
12. Engages until engine starts or energizer stops	0	0	3	yes or no
13. Keeps engine running by use of primer	4	0	1	yes or no
14. Checks oil pressure	4	0	20	yes or no
15. Changes prop pitch from high to low	2	0	13	yes or no
16. Locks primer	6	2	11	yes or no
17. Follows correct sequence	7	4	19	yes or no
TOTALS FOR EXERCISE 3	38	19	118	
Exercise 4: Run-up Check				
18. Checks rudder action	0	0	6	yes or no
19. Checks aileron and elevator action	0	0	4	yes or no

Required Operation	Errors			Criterion
	Transfer		Control	
	Link	SNJ	SNJ	
Exercise 4: Run-up Check				
20. Adjusts rudder pedals if necessary	1	0	7	yes or no
21. Adjusts seat if necessary	1	1	10	yes or no
22. Checks safety belts	4	1	10	yes or no
23. Checks fuel quantity in both tanks	5	2	5	yes or no
24. Checks gas on RESERVE	3	1	1	yes or no
25. Tests flap operation through full range and returns to UP position	1	0	3	yes or no
26. Checks hydraulic pressure	3	0	0	yes or no
27. Sets elevator trim at 10 o'clock position for takeoff	3	2	5	±1 inch
28. Sets rudder trim at 2 o'clock position for takeoff	3	2	5	±1 inch
29. Checks mixture RICH	2	4	19	yes or no
30. Checks both magnetos at 1700 r.p.m.	1	0	3	yes or no
31. Tests prop control through full range of operation and returns to low pitch	4	0	13	yes or no
32. Drains manifold pressure gauge	2	2	6	yes or no
33. Sets altimeter at zero	0	0	2	yes or no
34. Checks oil temperature	0	0	5	yes or no
35. Checks oil pressure	0	0	2	yes or no
36. Checks fuel pressure	0	0	2	yes or no
37. Checks cylinder head temperature	2	0	1	yes or no
38. Checks carburetor heat COLD	1	0	8	yes or no
39. Sets oil shutter for takeoff	2	0	8	yes or no
40. Checks primer locked	2	0	13	yes or no
41. Checks for traffic, 360-degree sweep	2	1	16	yes or no
42. Clears engine at 2000 r.p.m. minimum	1	1	14	yes or no
43. Follows correct sequence	17	2	33	yes or no
TOTALS FOR EXERCISE 4	60	19	201	

Required Operation	Errors: Transfer Link	Errors: Transfer SNJ	Errors: Control SNJ	Criterion
Exercise 5: Effect of Controls				
Part A-1: Use of Elevator				
44. Nose up: applies back elevator	0	0	0	yes or no
45. Nose down: applies forward elevator	0	0	0	yes or no
Part A-2: Use of Aileron				
46. Left wing down: applies left aileron	0	0	2	yes or no
47. Left wing up: applies right aileron	0	0	1	yes or no
48. Right wing down: applies right aileron	0	0	1	yes or no
49. Right wing up: applies left aileron	0	0	0	yes or no
Part A-3: Use of Rudder				
50. Nose left: applies left rudder	0	0	1	yes or no
51. Nose right: applies right rudder	0	0	0	yes or no
TOTALS FOR PART A	0	0	5	
Part B: Coordination of Aileron and Rudder				
52. Right wing up: applies left aileron and rudder	3	1	2	±½ ball
53. Right wing down: applies right aileron and rudder	23	5	2	±½ ball
54. Left wing up: applies right aileron and rudder	3	0	3	±½ ball
55. Left wing down: applies left aileron and rudder	24	2	5	±½ ball
TOTALS FOR PART B	53	8	12	
Part C: Power Adjustments				
56. Increases manifold pressure to 28 inches	0	0	1	±½ inch
57. Decreases manifold pressure to 16 inches	0	0	4	±½ inch
58. Increases manifold pressure to 25 inches	0	0	0	±½ inch
59. Increases r.p.m. to 2100	0	0	2	±50 r.p.m.
60. Decreases r.p.m. to 2000	3	0	0	±50 r.p.m.
61. Decreases r.p.m. to 1800	0	0	0	±50 r.p.m.
TOTALS FOR PART C	3	0	7	

Required Operation	Errors: Transfer Link	Errors: Transfer SNJ	Errors: Control SNJ	Criterion
Exercise 5: Effect of Controls				
Part D-1: Coordination of r.p.m. and Manifold Pressure (slow cruise)				
62. Adjusts throttle first	3	0	10	yes or no
63. Decreases power to 16 inches and 2000 r.p.m.	1	1	10	±½ inch ±50 r.p.m.
64. Completes task within 30 seconds	2	3	12	yes or no
Part D-2: (fast cruise)				
65. Adjusts prop control first	2	0	4	yes or no
66. Increases power to 2100 r.p.m. and 28 inches	0	2	3	±50 r.p.m. ±½ inch
67. Completes task within 30 seconds	3	0	5	yes or no
Part D-3: (normal cruise)				
68. Adjusts throttle first	3	1	5	yes or no
69. Decreases power to 25 inches and 1800 r.p.m.	3	0	5	±½ inch ±50 r.p.m.
70. Completes task within 30 seconds	1	0	7	yes or no
TOTALS FOR PART D	18	7	61	
Part E: Trim Tab Adjustments				
71. Nose high: rolls elevator trim control back	0	1	4	yes or no
72. Nose low: rolls elevator trim control forward	0	0	4	yes or no
73. Nose right: rolls rudder trim control forward	2	0	2	yes or no
74. Nose left: rolls rudder trim control back	0	0	2	yes or no
TOTALS FOR PART E	2	1	12	
TOTALS FOR EXERCISE 5	**76**	**16**	**97**	
Exercise 6: Straight and Level Flight				
Part A: Recovery from a Nose-High Attitude				
75. Holds wings level	0	0	0	±5 degrees
76. Returns nose to level	0	1	3	±5 degrees
77. Holds original heading	3	0	0	±5 degrees
78. Completes task within 10 seconds	12	0	11	yes or no
TOTALS FOR PART A	15	1	14	

Required Operation	Errors: Transfer Link	Errors: Transfer SNJ	Errors: Control SNJ	Criterion
Exercise 6: Straight and Level Flight				
Part B: Recovery from a Wing-Low Attitude (alternating right and left)				
79. Returns wings to level	1	0	0	±5 degrees
80. Holds nose level	0	1	1	±5 degrees
81. Coordinates aileron and rudder	5	4	18	±½ ball
82. Completes task within 10 seconds	17	4	9	yes or no
TOTALS FOR PART B	23	9	28	
Part C: Recovery from a Nose-Low Attitude				
83. Holds wings level	3	0	0	±5 degrees
84. Returns nose to level	1	0	5	±5 degrees
85. Holds original heading	2	0	0	±5 degrees
86. Completes task within 10 seconds	12	0	6	yes or no
TOTALS FOR PART C	18	0	11	
Part D: Recovery from a Steep Climbing Turn				
87. Returns wings to level	4	0	2	±5 degrees
88. Returns nose to level	5	0	5	±5 degrees
89. Coordinates rudder, aileron, and elevator; levels nose and wings simultaneously	28	18	64	±½ ball yes or no
90. Completes task within 10 seconds	33	5	15	yes or no
TOTALS FOR PART D	70	23	86	
Part E: Recovery from a Steep Diving Turn				
91. Returns wings to level	2	0	2	±5 degrees
92. Returns nose to level	2	2	14	±5 degrees
93. Coordinates rudder, aileron, and elevator; levels nose and wings simultaneously	25	2	29	±½ ball yes or no
94. Completes task within 10 seconds	25	4	9	yes or no
TOTALS FOR PART E	54	8	54	
TOTALS FOR EXERCISE 6	**180**	**41**	**193**	
Exercise 7: Trimming the Aircraft; Power and Speed Changes				
Part A: Holding Straight and Level Flight for Two Minutes				
95. Holds original altitude	8	6	13	±50 feet
96. Holds original heading	3	0	0	±10 degrees
TOTALS FOR PART A	11	6	13	

Required Operation	Errors: Transfer Link	Errors: Transfer SNJ	Errors: Control SNJ	Criterion
Exercise 7: Trimming the Aircraft; Power and Speed Changes				
Part B-1: Retrimming for Straight and Level Flight (during the trim procedure)				
97. Holds original altitude	15	1	36	±50 feet
98. Holds original heading	3	0	8	±10 degrees
99. Completes task within 60 seconds	8	1	18	yes or no
Part B-2: (for 10 seconds after trimming)				
100. Holds original altitude	1	2	16	±50 feet
101. Holds original heading	1	1	5	±10 degrees
TOTALS FOR PART B	28	5	83	
Part C-1: Changing Power Settings (establishing slow cruise)				
102. Adjusts throttle first	1	0	4	yes or no
103. Decreases power to 16 inches and 2000 r.p.m.	2	2	11	±½ inch ±50 r.p.m.
104. Holds original altitude	7	5	18	±50 feet
105. Holds original heading	1	1	4	±10 degrees
106. Completes task within 30 seconds	4	2	20	yes or no
Part C-2: (maintaining slow cruise for one minute)				
107. Holds original altitude	3	1	7	±50 feet
108. Holds original heading	0	0	1	±10 degrees
Part C-3: (establishing fast cruise)				
109. Adjusts prop control first	4	2	5	yes or no
110. Increases power to 2100 r.p.m. and 28 inches	0	1	8	±50 r.p.m. ±½ inch
111. Holds original altitude	5	2	22	±50 feet
112. Holds original heading	0	1	8	±10 degrees
113. Completes task within 30 seconds	2	0	16	yes or no
Part C-4: (maintaining fast cruise for one minute)				
114. Holds original altitude	6	1	13	±50 feet
115. Holds original heading	0	0	0	±10 degrees
Part C-5: (returning to normal cruise)				
116. Adjusts throttle first	2	0	6	yes or no
117. Decreases power to 25 inches and 1800 r.p.m.	3	0	7	±½ inch ±50 r.p.m.
118. Holds original altitude	7	13	17	±50 feet
119. Holds original heading	0	0	1	±10 degrees
120. Completes task within 30 seconds	3	1	10	yes or no
TOTALS FOR PART C	50	32	178	
TOTALS FOR EXERCISE 7	89	43	274	

Required Operation	Errors: Transfer Link	Errors: Transfer SNJ	Errors: Control SNJ	Criterion
Exercise 8: Level Turns				
Part A-1: 90-Degree Level Turn (entry)				
121. Looks right and left	5	3	9	yes or no
122. Coordinates aileron and rudder	5	0	6	±½ ball
123. Establishes 30-degree bank	9	5	14	±5 degrees
Part A-2: (maintaining turn)				
124. Coordinates aileron and rudder	5	2	5	±½ ball
125. Holds 30-degree bank	14	3	32	±5 degrees
Part A-3: (recovery)				
126. Coordinates aileron and rudder	7	4	21	±½ ball
127. Holds original altitude	23	27	59	±50 feet
128. Completes 90-degree turn	7	3	6	±10 degrees
TOTALS FOR PART A	75	47	152	
Part B-1: 180-Degree Level Turn (entry)				
129. Looks right and left	1	0	0	yes or no
130. Coordinates aileron and rudder	0	4	2	±½ ball
131. Establishes 30-degree bank	2	1	5	±5 degrees
Part B-2: (maintaining turn)				
132. Coordinates aileron and rudder	0	0	3	±½ ball
133. Holds 30-degree bank	13	15	18	±5 degrees
Part B-3: (recovery)				
134. Coordinates aileron and rudder	6	2	6	±½ ball
135. Holds original altitude	9	44	26	±50 feet
136. Completes 180-degree turn	2	6	0	±10 degrees
TOTALS FOR PART B	33	72	60	
Part C-1: 180-Degree Level Turn in Slow Flight (entry to slow flight)				
137. Adjusts throttle first	0	0	0	yes or no
138. Decreases power to 16 inches and 2000 r.p.m.	0	1	2	±½ inch ±50 r.p.m.
139. Completes task within 30 seconds	1	1	1	yes or no
140. Holds original altitude	2	1	7	±50 feet
141. Holds original heading	1	1	1	±10 degrees
Part C-2: (entry to turn)				
142. Looks right and left	7	0	3	yes or no
143. Coordinates aileron and rudder	0	0	2	±½ ball

Required Operation	Errors: Transfer Link	Errors: Transfer SNJ	Errors: Control SNJ	Criterion
Exercise 8: Level Turns				
144. Establishes 15-degree bank	2	0	2	±5 degrees
Part C-3: (maintaining turn)				
145. Holds original altitude	7	1	5	±50 feet
146. Holds 15-degree bank	11	1	13	±5 degrees
147. Coordinates aileron and rudder	4	1	3	±½ ball
Part C-4: (recovery)				
148. Coordinates aileron and rudder	7	2	3	±½ ball
149. Completes 180-degree turn	4	1	2	±10 degrees
150. Holds original altitude	3	1	7	±50 feet
TOTALS FOR PART C	49	11	51	
Part D-1: 360-Degree Steep Turn (entry)				
151. Looks right and left	0	3	1	yes or no
152. Coordinates aileron and rudder	0	0	3	±½ ball
153. Establishes 45-degree bank	1	1	7	±5 degrees
Part D-2: (maintaining turn)				
154. Coordinates aileron and rudder	1	1	8	±½ ball
155. Holds 45-degree bank	4	3	27	±5 degrees
Part D-3: (recovery)				
156. Holds original altitude	0	27	54	±100 feet
157. Coordinates aileron and rudder	5	3	16	±½ ball
158. Completes 360-degree turn	3	7	12	±10 degrees
TOTALS FOR PART D	14	45	128	
TOTALS FOR EXERCISE 8	171	175	391	
Exercise 9: Straight Climbs and Glides				
Part A-1: 1500-Foot Straight Climb (entry)				
159. Establishes straight climbing attitude of +7 degrees	2	1	1	±2 degrees
160. Holds wings level	0	0	0	±5 degrees
161. Adjusts prop control first	1	0	0	yes or no
162. Increases power to 2000 r.p.m. and 28 inches	2	0	2	±50 r.p.m. ±½ inch
163. Corrects for torque	1	7	11	±½ ball
Part A-2: (maintaining climb)				
164. Holds airspeed at 120 m.p.h.	1	3	7	±10 m.p.h.

Required Operation	Errors: Transfer Link	Errors: Transfer SNJ	Errors: Control SNJ	Criterion
Exercise 9: Straight Climbs and Glides				
165. Holds wings level	0	1	1	±5 degrees
166. Corrects for torque	0	5	5	±½ ball
167. Holds original heading	0	0	7	±10 degrees
Part A-3: (recovery)				
168. Returns nose to level	0	0	1	±5 degrees
169. Holds wings level	0	0	0	±5 degrees
170. Holds original heading	1	0	2	±10 degrees
171. Adjusts throttle first	0	0	2	yes or no
172. Decreases power to 25 inches and 1800 r.p.m.	1	0	1	±½ inch ±50 r.p.m.
173. Corrects for torque	1	2	3	±½ ball
174. Completes 1500-foot climb	7	5	17	±50 feet
TOTALS FOR PART A	17	24	60	
Part B-1: 1500-Foot Straight Glide (entry)				
175. Sets carburetor heat HOT	0	0	2	yes or no
176. Closes throttle	0	0	0	yes or no
177. Corrects for torque	7	6	16	±½ ball
178. Holds altitude until airspeed is 100 m.p.h.	12	3	27	±50 feet
179. Holds wings level	0	0	3	±5 degrees
Part B-2: (maintaining glide)				
180. Holds airspeed at 100 m.p.h.	4	0	9	±10 m.p.h.
181. Holds original heading	1	2	4	±10 degrees
182. Corrects for torque	0	1	9	±½ ball
Part B-3: (clearing engine)				
183. Clears engine at 1700 r.p.m. minimum after 500-foot descent	1	1	2	yes or no
184. Corrects for torque	2	5	9	±½ ball
185. Clears engine at 1700 r.p.m. minimum after 1000-foot descent	0	0	2	yes or no
186. Corrects for torque	2	5	14	±½ ball
Part B-4: (recovery)				
187. Increases manifold pressure to 25 inches	0	1	2	±½ inch
188. Holds original heading	1	0	5	±10 degrees
189. Corrects for torque	4	13	36	±½ ball
190. Sets carburetor heat COLD	0	5	5	yes or no
191. Completes 1500-foot glide	5	8	21	±50 feet
TOTALS FOR PART B	39	50	166	
TOTALS FOR EXERCISE 9	56	74	226	

Required Operation	Errors: Transfer Link	Errors: Transfer SNJ	Errors: Control SNJ	Criterion
Exercise 10: Climbing and Gliding Turns				
Part A-1: 1500-Foot Climbing Turn (entry)				
192. Establishes straight climbing attitude of +7 degrees	0	0	0	±2 degrees
193. Adjusts prop control first	0	0	0	yes or no
194. Increases power to 2000 r.p.m. and 28 inches	0	1	1	±50 r.p.m. ±½ inch
195. Holds straight climb until airspeed is 120 m.p.h.	1	1	5	±10 m.p.h.
196. Corrects for torque	0	2	8	±½ ball
197. Establishes 15-degree bank	2	0	2	±5 degrees
198. Coordinates aileron and rudder with correction for torque	0	1	7	±½ ball
Part A-2: (maintaining turn)				
199. Holds airspeed at 120 m.p.h.	0	1	5	±10 m.p.h.
200. Coordinates aileron and rudder with correction for torque	0	3	11	±½ ball
201. Holds 15-degree bank	0	1	12	±5 degrees
Part A-3: (recovery)				
202. Returns nose to level	0	0	2	±5 degrees
203. Returns wings to level	0	0	1	±5 degrees
204. Coordinates rudder, aileron, and elevator; levels nose and wings simultaneously	3	2	6	±½ ball yes or no
205. Adjusts throttle first	0	0	1	yes or no
206. Decreases power to 25 inches and 1800 r.p.m.	0	1	0	±½ inch ±50 r.p.m.
207. Corrects for torque	1	5	14	±½ ball
208. Completes 1500-foot climb	2	4	24	±50 feet
TOTALS FOR PART A	9	22	99	
Part B-1: 1500-Foot Gliding Turn (entry)				
209. Sets carburetor heat HOT	0	1	1	yes or no
210. Closes throttle	0	0	0	yes or no
211. Corrects for torque	0	3	4	±½ ball
212. Holds altitude until airspeed is 100 m.p.h.	0	4	6	±50 feet
213. Holds wings level	0	0	0	±5 degrees
214. Holds original heading	1	1	1	±10 degrees
215. Establishes gliding attitude at 100 m.p.h.	2	0	2	±10 m.p.h.
216. Establishes 15-degree bank	1	1	1	±5 degrees
217. Coordinates aileron and rudder with correction for torque	0	4	4	±½ ball

Required Operation	Errors: Transfer Link	Errors: Transfer SNJ	Errors: Control SNJ	Criterion
Exercise 10: Climbing and Gliding Turns				
Part B-2: (maintaining turn)				
218. Holds airspeed at 100 m.p.h.	0	1	5	±10 m.p.h.
219. Holds 15-degree bank	0	2	7	±5 degrees
220. Coordinates aileron and rudder with correction for torque	0	0	2	±½ ball
Part B-3: (clearing engine)				
221. Clears engine at 1700 r.p.m. minimum after 500-foot descent	2	1	1	yes or no
222. Corrects for torque	1	0	1	±½ ball
223. Clears engine at 1700 r.p.m. minimum after 1000-foot descent	0	0	0	yes or no
224. Corrects for torque	0	0	0	±½ ball
Part B-4: (recovery)				
225. Returns nose to level	0	0	1	±5 degrees
226. Returns wings to level	0	0	0	±5 degrees
227. Coordinates aileron and rudder with correction for torque	0	5	5	±½ ball
228. Increases manifold pressure to 25 inches	0	0	1	±½ inch
229. Corrects for torque	3	16	20	±½ ball
220. Completes 1500-foot glide	4	2	5	±50 feet
TOTALS FOR PART B	14	41	67	
TOTALS FOR EXERCISE 10	23	63	166	
Exercise 11: Stalls				
Part A-1: Normal Stall, Power On (entry)				
231. Establishes stall attitude of +25 degrees	1	0	1	±3 degrees
232. Holds wings level	0	0	1	±5 degrees
233. Corrects for torque	0	0	5	±½ ball
234. Holds original heading	0	0	3	±10 degrees
Part A-2: (maintaining stall approach attitude)				
235. Holds stall attitude of +25 degrees until break	0	0	4	±3 degrees
236. Holds wings level	0	0	5	±5 degrees
237. Corrects for torque until airspeed is 75 m.p.h.	0	4	20	±½ ball
238. Holds original heading	0	3	12	±10 degrees

Required Operation	Errors: Transfer Link	Errors: Transfer SNJ	Errors: Control SNJ	Criterion
Exercise 11: Stalls				
Part A-3: (recovery)				
239. Begins recovery at break	0	2	6	yes or no
240. Applies definite forward elevator	1	0	4	yes or no
241. Increases power smoothly	0	0	8	yes or no
242. Holds original heading	3	8	18	yes or no
243. Recovers without secondary stall	0	0	0	yes or no
TOTALS FOR PART A	5	17	87	
Part B-1: Normal Stall, Power Off (entry)				
244. Sets carburetor heat HOT	0	0	0	yes or no
245. Closes throttle	0	0	1	yes or no
246. Corrects for torque	0	2	11	±½ ball
247. Holds altitude until airspeed is 100 m.p.h.	4	0	6	±50 feet
248. Establishes stall attitude of +7 degrees	0	0	1	±2 degrees
249. Holds wings level	0	0	0	±5 degrees
250. Holds original heading	1	2	5	±10 degrees
Part B-2: (maintaining stall approach attitude)				
251. Holds stall attitude of +7 degrees until break	0	0	3	±2 degrees
252. Holds wings level	0	0	3	±10 degrees
253. Holds original heading	0	3	9	±10 degrees
Part B-3: (recovery)				
254. Begins recovery at break	1	1	5	yes or no
255. Opens throttle smoothly	0	0	2	yes or no
256. Holds original heading	1	2	9	±10 degrees
257. Recovers without secondary stall	0	0	0	yes or no
TOTALS FOR PART B	7	10	55	
Part C-1: Partial Stall, Power On (entry)				
258. Establishes stall attitude of +25 degrees	0	0	0	±3 degrees
259. Holds wings level	0	0	0	±5 degrees
260. Corrects for torque	0	0	0	±½ ball
261. Holds original heading	0	0	1	±10 degrees
Part C-2: (maintaining stall approach attitude)				
262. Holds stall attitude of +25 degrees until recovery	0	0	0	±3 degrees
263. Holds wings level	0	0	1	±5 degrees

Required Operation	Errors: Transfer Link	Errors: Transfer SNJ	Errors: Control SNJ	Criterion
Exercise 11: Stalls				
264. Corrects for torque until airspeed is 75 m.p.h.	0	2	7	±½ ball
265. Holds original heading	0	1	4	±10 degrees
Part C-3: (recovery)				
266. Holds stall approach attitude until airspeed is 65 m.p.h. or less	0	0	0	yes or no
267. Recovers before break	1	0	0	yes or no
268. Applies definite forward elevator	0	0	1	yes or no
269. Increases power smoothly	0	1	4	yes or no
270. Holds original heading	1	2	3	±10 degrees
271. Recovers without secondary stall	0	0	0	yes or no
TOTALS FOR PART C	2	6	21	
Part D-1: Partial Stall, Power Off (entry)				
272. Sets carburetor heat HOT	0	0	0	yes or no
273. Closes throttle	0	0	0	yes or no
274. Corrects for torque	0	3	3	±½ ball
275. Holds altitude until airspeed is 100 m.p.h.	0	0	2	±50 feet
276. Establishes stall attitude of +7 degrees	0	0	1	±2 degrees
277. Holds wings level	0	0	0	±5 degrees
278. Holds original heading	0	0	0	±10 degrees
279. Corrects for torque	0	0	1	±½ ball
Part D-2: (maintaining stall approach attitude)				
280. Holds stall attitude of +7 degrees until airspeed is 75 m.p.h. or less	0	0	0	±2 degrees
281. Holds wings level	0	0	0	±5 degrees
282. Corrects for torque until airspeed is 80 m.p.h.	0	0	0	±½ ball
283. Holds original heading	0	1	1	±10 degrees
Part D-3: (recovery)				
284. Recovers before break	0	1	0	yes or no
285. Opens throttle smoothly	0	1	2	yes or no
286. Holds original heading	0	0	0	±10 degrees
287. Recovers without secondary stall	0	0	0	yes or no
TOTALS FOR PART D	0	6	10	

Required Operation	Errors Transfer Link	Errors Transfer SNJ	Errors Control SNJ	Criterion
Exercise 11: Stalls				
Part E-1: Normal Stall from a Slow-Flight Climbing Turn (entry to slow-flight climbing turn)				
288. Establishes straight climb at 80 m.p.h.	0	0	0	±10 m.p.h.
289. Holds original heading until airspeed is 80 m.p.h.	0	1	1	±10 degrees
290. Establishes 15-degree bank	0	0	0	±5 degrees
291. Corrects for torque	0	3	4	±½ ball
Part E-2: (maintaining slow-flight turn for 90 degrees)				
292. Holds 15-degree bank	1	4	5	±5 degrees
293. Holds airspeed at 80 m.p.h.	1	3	3	±10 m.p.h.
294. Coordinates aileron and rudder with correction for torque	1	3	3	±½ ball
295. Completes 90-degree turn	4	1	2	±10 degrees
Part E-3: (entry to stall)				
296. Holds 15-degree bank until break	3	1	4	±5 degrees
297. Gets definite break	0	0	0	yes or no
Part E-4: (recovery)				
298. Applies definite elevator and rudder movements	0	0	0	yes or no
299. Increases power smoothly	0	0	1	yes or no
300. Recovers without secondary stall	0	0	0	yes or no
TOTALS FOR PART E	10	16	23	
Part F-1: Normal Stall from a Slow-Flight Gliding Turn (entry to slow-flight gliding turn)				
301. Sets carburetor heat HOT	0	0	0	yes or no
302. Closes throttle	0	0	0	yes or no
303. Holds altitude until airspeed is 85 m.p.h.	0	3	4	±50 feet ±10 m.p.h.
304. Corrects for torque	1	1	3	±5 degrees
305. Establishes 15-degree bank	1	0	0	±5 degrees
Part F-2: (maintaining slow-flight turn for 90 degrees)				
306. Holds 15-degree bank	1	1	2	±5 degrees
307. Holds airspeed at 85 m.p.h.	0	1	0	±10 m.p.h.
308. Coordinates aileron and rudder with correction for torque	1	4	3	±½ ball
309. Completes 90-degree turn	0	0	1	±10 degrees
Part F-3: (entry to stall)				
310. Holds 15-degree bank until break	0	4	1	±5 degrees

Required Operation	Errors: Transfer Link	Errors: Transfer SNJ	Errors: Control SNJ	Criterion
Exercise 11: Stalls				
311. Gets definite break	0	0	2	yes or no
Part F-4: (recovery)				
312. Applies definite elevator and rudder movements	0	0	1	yes or no
313. Opens throttle smoothly	0	0	2	yes or no
314. Recovers without secondary stall	0	0	1	yes or no
TOTALS FOR PART F	4	14	20	
Part G: Landing Procedure Stall				
315. Sets carburetor heat HOT	0	0	0	yes or no
316. Sets mixture RICH	0	0	1	yes or no
317. Turns gas on RESERVE	1	0	0	yes or no
318. Sets r.p.m. at 2100	3	1	4	±50 r.p.m.
319. Depresses hydraulic power button	1	2	1	yes or no
320. Closes throttle	3	0	0	yes or no
321. Lowers landing gear	2	0	0	yes or no
322. Reduces airspeed to 100 m.p.h.	3	1	0	±5 m.p.h.
323. Holds altitude until airspeed is 100 m.p.h.	4	1	4	±50 feet
324. Makes 90-degree gliding turn	3	3	3	±10 degrees
325. Lowers full flaps	0	0	0	yes or no
326. Holds airspeed at 90 m.p.h. until signal to stall	5	1	5	±10 m.p.h.
327. Brings nose to three-point attitude	0	1	2	±5 degrees
328. Gets definite break	0	0	2	yes or no
329. Holds approach heading	2	0	1	±10 degrees
TOTALS FOR PART G	27	10	23	
TOTALS FOR EXERCISE 11	55	79	239	
Exercise 12: Entry to the Traffic Pattern				
330. Sets mixture RICH	0	0	0	yes or no
331. Turns gas on RESERVE	0	0	0	yes or no
332. Sets r.p.m. at 2000	0	0	3	±50 r.p.m.
333. Lowers landing gear	1	0	1	yes or no
334. Enters 45-degree leg two miles out	4	1	6	±½ mile
335. Flies track 45 degrees less than heading of downwind leg	2	3	6	±10 degrees

Required Operation	Errors: Transfer Link	Errors: Transfer SNJ	Errors: Control SNJ	Criterion
Exercise 12: Entry to the Traffic Pattern				
336. Sets manifold pressure at 18 inches	1	2	4	±½ inch
337. Holds pattern altitude	7	2	7	±100 feet
338. Looks right and left	7	1	6	yes or no
339. Intersects downwind leg within first one-third	6	2	7	yes or no
340. Makes turn to heading of downwind leg	4	2	4	±10 degrees
341. Flies downwind leg parallel to runway	2	1	2	±10 degrees
TOTALS FOR EXERCISE 12	**34**	**14**	**46**	
Exercise 13: Flying the Traffic Pattern				
Takeoff Leg				
342. Decreases manifold pressure to 30 inches when airborne	1	0	0	±1 inch
343. Decreases r.p.m. to 2100	5	0	1	±50 r.p.m.
344. Retracts landing gear	1	1	0	yes or no
345. Holds airspeed at 120 m.p.h.	1	0	2	±10 m.p.h.
346. Holds runway heading	2	0	0	±10 degrees
347. Levels off at 400 feet	3	0	1	±50 feet
348. Decreases manifold pressure to 23 inches	3	1	2	±1 inch
Crosswind Leg				
349. Looks right and left	1	1	4	yes or no
350. Makes level turn to crosswind leg heading	2	4	7	±100 feet ±10 degrees
351. Increases manifold pressure to 30 inches maximum	2	0	4	yes or no
352. Climbs to 600 feet	1	0	3	±50 feet
Downwind Leg				
353. Looks right and left	3	1	7	yes or no
354. Makes climbing turn to downwind heading at 800 feet	1	0	2	±10 degrees ±100 feet
355. Flies downwind leg ¾ mile out from runway	1	1	6	±¼ mile
356. Flies downwind leg parallel to runway	0	1	8	±10 degrees
357. Closes throttle	3	0	0	yes or no
358. Lowers landing gear	1	0	0	yes or no

Required Operation	Errors: Transfer Link	Errors: Transfer SNJ	Errors: Control SNJ	Criterion
Exercise 13: Flying the Traffic Pattern				
359. Increases manifold pressure to 18 inches	0	0	4	−1 to + 2 inches
360. Holds pattern altitude	5	3	11	±100 feet
Base Leg				
361. Looks right and left	1	0	4	yes or no
362. Makes level turn to base leg heading	2	0	5	±100 feet ±10 degrees
363. Flies base leg ½ mile out from end of runway	0	0	8	±¼ mile
Final Approach				
364. Looks right and left	4	0	8	yes or no
365. Makes turn to final approach and rolls out lined up within lateral limits of runway	0	2	10	yes or no
366. Closes throttle	5	0	1	yes or no
367. Lowers full flaps	1	1	3	yes or no
368. Holds airspeed at 90 m.p.h.	6	2	3	±10 m.p.h.
369. Holds flight path lined up within lateral limits of runway until touchdown	0	0	3	yes or no
370. Applies power as needed to extend glide to runway	0	0	4	yes or no
TOTALS FOR EXERCISE 13	55	18	111	

Appendix B: Criteria and Error Tabulation for Each Performance Item, Instrument Flight Experiment (Exercises 1–6)

Required Operation	Errors: Transfer Link	Errors: Transfer SNJ	Errors: Control SNJ	Criterion
Exercise 1: Use of the Artificial Horizon				
Part A: Straight and Level Flight				
1. Holds original altitude	4	1	9	±200 feet
2. Holds wings level	3	0	2	±5 degrees
3. Holds original heading	6	6	13	±20 degrees
4. Holds nose level	0	1	1	±2 degrees
TOTALS FOR PART A	13	8	25	
Part B-1: 180-Degree Level Turn (entry)				
5. Establishes 30-degree bank	5	0	2	±5 degrees
6. Holds nose level	8	1	4	±2 degrees
7. Coordinates aileron and rudder	0	0	0	±½ ball
Part B-2: (maintaining turn)				
8. Holds 30-degree bank	6	4	8	±5 degrees
9. Holds nose level	5	4	11	±2 degrees
10. Coordinates aileron and rudder	0	0	1	±½ ball
Part B-3: (recovery)				
11. Returns wings to level	5	0	0	±5 degrees
12. Holds original altitude throughout maneuver	4	9	26	±100 feet
13. Coordinates aileron and rudder	0	1	0	±½ ball
TOTALS FOR PART B	33	19	52	
Part C-1: Straight Climb (entry)				
14. Establishes straight climbing attitude of +7 degrees	1	2	9	±2 degrees
15. Adjusts prop control first	4	0	9	yes or no

Required Operation	Errors			Criterion
	Transfer		Control	
	Link	SNJ	SNJ	
Exercise 1: Use of the Artificial Horizon				
16. Increases power to 2000 r.p.m. and 28 inches	1	1	7	±50 r.p.m. ±1 inch
17. Corrects for torque	0	7	1	±½ ball
Part C-2: (maintaining climb)				
18. Holds straight climbing attitude of +7 degrees	10	10	12	±2 degrees
19. Holds wings level	9	8	21	±5 degrees
20. Holds airspeed at 120 m.p.h.	2	8	15	±10 m.p.h.
21. Corrects for torque	0	7	3	±½ ball
Part C-3: (recovery)				
22. Returns nose to level	2	4	13	±2 degrees
23. Holds wings level	9	2	12	±5 degrees
24. Adjusts throttle first	5	0	3	yes or no
25. Decreases power to 25 inches and 1800 r.p.m.	2	1	9	±1 inch ±50 r.p.m.
26. Holds original heading throughout maneuver	16	9	35	±10 degrees
27. Corrects for torque	0	4	2	±½ ball
TOTALS FOR PART C	61	63	151	
Part D-1: Straight Partial Power Descent (entry)				
28. Decreases manifold pressure to 14 inches	0	2	4	±1 inch
29. Establishes straight descending attitude of −2 degrees	9	2	10	±2 degrees
30. Corrects for torque	2	1	1	±½ ball
Part D-2: (maintaining descent)				
31. Holds straight descending attitude of −2 degrees	6	2	5	±2 degrees
32. Holds wings level	4	1	11	±5 degrees
33. Holds airspeed at 120 m.p.h.	3	4	2	±10 m.p.h.
34. Corrects for torque	2	1	0	±½ ball
Part D-3: (recovery)				
35. Increases manifold pressure to 25 inches	4	1	3	±1 inch
36. Holds wings level	1	3	7	±5 degrees
37. Returns nose to level	1	1	4	±2 degrees
38. Holds original heading throughout maneuver	8	4	14	±10 degrees
39. Corrects for torque	0	5	1	±½ ball
TOTALS FOR PART D	40	27	62	
TOTALS FOR EXERCISE 1	147	117	290	

Required Operation	Errors: Transfer Link	Errors: Transfer SNJ	Errors: Control SNJ	Criterion
Exercise 2: Use of the Full Panel				
Part A: Straight and Level Flight				
40. Holds original altitude	4	3	6	±50 feet
41. Holds wings level	1	0	1	±5 degrees
42. Holds original heading	2	0	8	±5 degrees
43. Holds nose level	0	0	1	±2 degrees
TOTALS FOR PART A	7	3	16	
Part B-1: 180-Degree Level Turn (entry)				
44. Establishes 20-degree bank	1	1	0	±5 degrees
45. Holds nose level	0	0	0	±2 degrees
46. Coordinates aileron and rudder	1	0	0	±½ ball
Part B-2: (maintaining turn)				
47. Holds 20-degree bank	9	3	2	±5 degrees
48. Holds nose level	0	0	2	±2 degrees
49. Coordinates aileron and rudder	0	0	0	±½ ball
Part B-3: (recovery)				
50. Returns wings to level	1	1	2	±5 degrees
51. Holds original altitude throughout maneuver	8	5	10	±50 feet
52. Rolls out on desired heading	4	5	7	±5 degrees
53. Coordinates aileron and rudder	0	1	0	±½ ball
TOTALS FOR PART B	24	16	23	
Part C-1: Straight Climb (entry)				
54. Establishes straight climbing attitude of +7 degrees	1	1	3	±2 degrees
55. Adjusts power when airspeed reaches 125–120 m.p.h.	1	0	0	yes or no
56. Adjusts prop control first	1	0	0	yes or no
57. Adjusts power to 2000 r.p.m. and 25 inches	3	2	1	±50 r.p.m. ±1 inch
58. Corrects for torque	1	3	0	±½ ball
Part C-2: (maintaining climb)				
59. Holds wings level	3	7	1	±5 degrees
60. Holds airspeed at 120 m.p.h.	3	4	4	±10 m.p.h.
61. Corrects for torque	0	3	0	±½ ball
Part C-3: (recovery)				
62. Holds wings level	4	2	0	±5 degrees
63. Decreases power when air-				

Required Operation	Errors: Transfer Link	Errors: Transfer SNJ	Errors: Control SNJ	Criterion
Exercise 2: Use of the Full Panel				
speed reaches 135–140 m.p.h.	7	1	3	yes or no
64. Decreases power to 25 inches and 1800 r.p.m.; adjusts throttle first	1	2	3	±1 inch ±50 r.p.m. yes or no
65. Corrects for torque	1	0	0	±½ ball
66. Completes 1000-foot climb	4	4	3	±100 feet
67. Holds original heading	6	15	16	±5 degrees
TOTALS FOR PART C	36	44	34	
Part D-1: Straight Partial Power Descent (entry)				
68. Decreases manifold pressure to 14 inches	0	0	0	±1 inch
69. Holds altitude until airspeed reaches 120–125 m.p.h.	0	0	4	±100 feet
70. Holds wings level	1	1	0	±5 degrees
71. Corrects for torque	0	0	0	±½ ball
Part D-2: (maintaining descent)				
72. Holds nose attitude at −2 degrees	0	0	2	±2 degrees
73. Holds wings level	1	1	0	±5 degrees
74. Holds airspeed at 120 m.p.h.	1	3	1	±10 m.p.h.
75. Corrects for torque	0	0	0	±½ ball
Part D-3: (recovery)				
76. Increases manifold pressure to 25 inches	0	0	2	±1 inch
77. Holds wings level	1	0	1	±5 degrees
78. Corrects for torque	0	1	0	±½ ball
79. Completes 1000-foot descent	0	0	2	±100 feet
80. Holds original heading	7	2	7	±5 degrees
TOTALS FOR PART D	11	8	19	
TOTALS FOR EXERCISE 2	**78**	**71**	**92**	
Exercise 3: Standard Rate Climbs, Descents, and Level Turns				
Part A: Straight and Level Flight for Two Minutes				
81. Holds original altitude	2	1	3	±50 feet
82. Holds wings level	0	0	0	±5 degrees
83. Holds original heading	1	0	1	±5 degrees
84. Times two-minute interval	2	0	1	±5 seconds
TOTALS FOR PART A	5	1	5	

Required Operation	Errors: Transfer Link	Errors: Transfer SNJ	Errors: Control SNJ	Criterion
Exercise 3: Standard Rate Climbs, Descents, and Level Turns				
Part B-1: 180-Degree Standard Rate Level Turn (entry)				
85. Establishes standard rate of turn	7	2	3	±½ needle
86. Coordinates aileron and rudder	4	1	0	±½ ball
Part B-2: (maintaining turn)				
87. Coordinates aileron and rudder	2	0	0	±½ ball
88. Completes 90 degrees of turn in 30 seconds	17	8	9	±5 degrees
Part B-3: (recovery)				
89. Holds nose level	0	0	12	±2 degrees
90. Holds altitude throughout maneuver	32	15	27	±50 feet
91. Completes 180-degree turn in one minute	35	9	16	±5 degrees
92. Coordinates aileron and rudder	0	6	0	±½ ball
TOTALS FOR PART B	97	41	67	
Part C-1: 1000-Foot Straight Climb at 500 Feet per Minute (entry)				
93. Holds wings level	0	0	2	±5 degrees
94. Increases pitch attitude until airspeed reaches 130–125 m.p.h.	0	0	0	yes or no
95. Increases r.p.m. to 2000 (adjusts throttle as needed to maintain rate of climb)	1	1	0	±50 r.p.m.
96. Holds original heading	2	2	7	±5 degrees
97. Corrects for torque	0	0	0	±½ ball
Part C-2: (maintaining climb)				
98. Holds wings level	0	1	1	±½ ball
99. Holds airspeed at 120 m.p.h.	5	3	2	±10 m.p.h.
100. Corrects for torque	0	3	0	±½ ball
101. Completes 500-foot climb in one minute	17	7	23	±50 feet
102. Holds original heading	4	3	9	±5 degrees
Part C-3: (recovery)				
103. Holds wings level	0	1	0	±5 degrees
104. Completes 1000-foot climb in two minutes	18	4	13	±50 feet

Required Operation	Errors: Transfer Link	Errors: Transfer SNJ	Errors: Control SNJ	Criterion
Exercise 3: Standard Rate Climbs, Descents, and Level Turns				
105. Holds original heading until airspeed is 135 m.p.h.	1	2	8	±5 degrees
106. Holds new altitude until airspeed is 135 m.p.h.	4	3	12	±50 feet
107. Corrects for torque until airspeed is 135 m.p.h.	0	1	0	±½ ball
TOTALS FOR PART C	52	31	77	
Part D-1: 1000-Foot Straight Partial Power Descent at 500 Feet per Minute (entry)				
108. Reduces manifold pressure to 14 inches	0	0	1	±1 inch
109. Holds original altitude until airspeed is 120 m.p.h.	3	2	3	±50 feet
110. Holds wings level	1	0	1	±5 degrees
111. Holds original heading	9	2	5	±5 degrees
112. Corrects for torque	1	0	1	±½ ball
Part D-2: (maintaining descent)				
113. Holds wings level	3	0	1	±5 degrees
114. Holds airspeed at 120 m.p.h.	3	6	6	±10 degrees
115. Corrects for torque	0	0	0	±½ ball
116. Completes 500-foot descent in one minute	14	4	10	±50 feet
117. Holds original heading	7	4	3	±5 degrees
Part D-3: (recovery)				
118. Holds wings level	0	0	0	±5 degrees
119. Completes 1000-foot descent in two minutes	11	8	9	±50 feet
120. Adjusts power to 1800 r.p.m. and 25 inches	1	1	0	±50 r.p.m.
121. Holds original heading until airspeed is 135 m.p.h.	5	1	4	±5 degrees
122. Holds new altitude until airspeed is 135 m.p.h.	9	3	8	±50 feet
123. Corrects for torque until airspeed is 135 m.p.h.	0	3	0	±½ ball
TOTALS FOR PART D	67	34	52	
TOTALS FOR EXERCISE 3	221	107	201	

Required Operation	Errors			Criterion
	Transfer		Control	
	Link	SNJ	SNJ	
Exercise 4: Slow Flight				
Part A-1: Straight and Level Flight for Two Minutes (entry)				
124. Adjusts power to 16 inches and 2000 r.p.m.; adjusts throttle first	1	1	3	±1 inch ±50 r.p.m.
125. Corrects for torque	0	0	1	±½ ball
126. Holds original altitude until airspeed is 120 m.p.h.	1	3	1	±50 feet
127. Holds original heading until airspeed is 120 m.p.h.	4	1	2	±5 degrees
Part A-2: (maintaining slow flight)				
128. Holds original altitude	3	5	7	±50 feet
129. Holds original heading	1	3	2	±5 degrees
130. Holds airspeed at 120 m.p.h.	1	2	0	±10 m.p.h.
131. Corrects for torque	0	0	1	±½ ball
Part A-3: (recovery)				
132. Adjusts power to 1800 r.p.m. and 25 inches; adjusts prop control first	0	1	1	±50 r.p.m. ±1 inch
133. Corrects for torque	0	0	0	±½ ball
134. Holds original altitude until airspeed is 140 m.p.h.	2	2	10	±50 feet
135. Holds original heading until airspeed is 140 m.p.h.	0	3	4	±5 degrees
TOTALS FOR PART A	13	21	32	
Part B: 45-Degree Standard Rate Level Turn in Slow Flight				
136. Holds original altitude	2	5	6	±50 feet
137. Completes 45-degree turn	8	13	11	±5 degrees
138. Completes turn in 15 seconds	4	3	1	±5 seconds
139. Coordinates aileron and rudder	3	0	0	±½ ball
TOTALS FOR PART B	17	21	18	
Part C: 90-Degree Standard Rate Level Turn in Slow Flight				
140. Holds original altitude	0	1	18	±50 feet
141. Completes 90-degree turn	4	2	10	±5 degrees
142. Completes turn in 30 seconds	1	1	5	±5 seconds
143. Coordinates aileron and rudder	0	0	0	±½ ball
TOTALS FOR PART C	5	4	33	

Required Operation	Errors: Transfer Link	Errors: Transfer SNJ	Errors: Control SNJ	Criterion
Exercise 4: Slow Flight				
Part D: 180-Degree Standard Rate Level Turn in Slow Flight				
144. Holds original altitude	3	6	5	±50 feet
145. Completes 180-degree turn	1	2	2	±5 degrees
146. Completes turn in one minute	1	0	4	±5 seconds
147. Coordinates aileron and rudder	2	0	0	±½ ball
TOTALS FOR PART D	7	8	11	
TOTALS FOR EXERCISE 4	42	54	94	
Exercise 5: Rated Climbing and Descending Turns				
Part A-1: 360-Degree Standard Rate Climbing Turn (first 30 seconds)				
148. Holds airspeed at 120 m.p.h.	0	0	2	±10 m.p.h.
149. Completes 90 degrees of turn	22	4	8	±5 degrees
150. Completes 250-foot climb	11	7	11	±50 feet
151. Coordinates aileron and rudder	1	1	0	±½ ball
Part A-2: (second 30 seconds)				
152. Holds airspeed at 120 m.p.h.	2	0	3	±10 m.p.h.
153. Completes 180 degrees of turn	23	6	9	±5 degrees
154. Completes 500-foot climb	16	7	13	±50 feet
155. Coordinates aileron and rudder	0	0	1	±½ ball
Part A-3: (third 30 seconds)				
156. Holds airspeed at 120 m.p.h.	4	3	2	±10 m.p.h.
157. Completes 270 degrees of turn	28	11	14	±5 degrees
158. Completes 750-foot climb	21	6	22	±50 feet
159. Coordinates aileron and rudder	0	1	1	±½ ball
Part A-4: (fourth 30 seconds)				
160. Holds airspeed at 120 m.p.h.	5	3	3	±10 m.p.h.
161. Completes 360 degrees of turn	31	14	11	±5 degrees
162. Completes 1000-foot climb	23	12	20	±50 feet
163. Coordinates aileron and rudder	0	0	1	±½ ball
TOTALS FOR PART A	187	75	121	
Part B-1: 360-Degree Standard Rate Gliding Turn (first 30 seconds)				
164. Holds airspeed at 120 m.p.h.	3	0	5	±10 m.p.h.

Required Operation	Errors: Transfer Link	Errors: Transfer SNJ	Errors: Control SNJ	Criterion
Exercise 5: Rated Climbing and Descending Turns				
165. Completes 90 degrees of turn	9	1	13	±5 degrees
166. Completes 250-foot glide	12	2	23	±50 feet
167. Coordinates aileron and rudder	0	0	0	±½ ball
Part B-2: (second 30 seconds)				
168. Holds airspeed at 120 m.p.h.	2	0	4	±10 m.p.h.
169. Completes 180 degrees of turn	12	3	30	±5 degrees
170. Completes 500-foot glide	11	6	20	±50 feet
171. Coordinates aileron and rudder	0	0	0	±½ ball
Part B-3: (third 30 seconds)				
172. Holds airspeed at 120 m.p.h.	1	1	2	±10 m.p.h.
173. Completes 270 degrees of turn	9	6	31	±5 degrees
174. Completes 750-foot glide	7	5	43	±50 feet
175. Coordinates aileron and rudder	0	0	0	±½ ball
Part B-4: (fourth 30 seconds)				
176. Holds airspeed at 120 m.p.h.	1	0	4	±10 m.p.h.
177. Completes 360 degrees of turn	11	5	31	±5 degrees
178. Completes 1000-foot glide	9	3	39	±50 feet
179. Coordinates aileron and rudder	0	0	0	±½ ball
TOTALS FOR PART B	87	32	245	
TOTALS FOR EXERCISE 5	274	107	366	
Exercise 6: Steep Turns; Power-On and Power-Off Stalls				
Part A-1: 360-Degree Steep Turn (entry)				
180. Establishes 45-degree bank	2	1	0	±5 degrees
181. Holds nose level	0	0	3	±5 degrees
182. Coordinates aileron and rudder	3	0	0	±½ ball
Part A-2: (maintaining turn)				
183. Holds 45-degree bank	6	3	12	±5 degrees
184. Holds original altitude	2	3	8	±100 feet
185. Coordinates aileron and rudder	4	0	0	±½ ball
Part A-3: (recovery)				
186. Completes 360-degree turn	33	2	15	±5 degrees

Required Operation	Errors: Transfer Link	Errors: Transfer SNJ	Errors: Control SNJ	Criterion
Exercise 6: Steep Turns; Power-On and Power-Off Stalls				
187. Returns wings to level and holds for 10 seconds after roll-out	1	0	2	±5 degrees
188. Holds original altitude for 10 seconds after roll-out	2	1	9	±100 feet
189. Coordinates aileron and rudder	27	0	0	±½ ball
TOTALS FOR PART A	80	10	49	
Part B-1: Normal Stall, Power On (entry)				
190. Establishes stall attitude of 25 degrees	3	0	1	±5 degrees
191. Corrects for torque	0	0	0	±½ ball
Part B-2: (maintaining stall approach attitude)				
192. Holds original heading	0	1	5	±10 degrees
193. Holds wings level	1	0	4	±5 degrees
194. Holds stall attitude of 25 degrees until break	1	1	4	±5 degrees
195. Corrects for torque until airspeed is 75 m.p.h.	0	0	0	±½ ball
Part B-3: (recovery)				
196. Begins recovery at break	0	0	0	yes or no
197. Increases power smoothly	0	1	3	yes or no
198. Recovers with original heading	5	5	7	±10 degrees
199. Recovers without secondary stall	1	1	1	yes or no
200. Returns nose to level by the time airspeed is 100 m.p.h.	1	3	11	±2 degrees
201. Returns wings to level by the time airspeed is 100 m.p.h.	3	2	8	±5 degrees
TOTALS FOR PART B	15	14	44	
Part C-1: Normal Stall, Power Off in a 20-Degree Bank (entry; throttle closed)				
202. Holds original altitude until airspeed is 120 m.p.h.	0	2	4	±50 feet
203. Holds original heading until airspeed is 120 m.p.h.	2	1	0	±5 degrees
204. Holds wings level until airspeed is 120 m.p.h.	0	0	0	±5 degrees
205. Corrects for torque	2	0	0	±½ ball
206. Establishes 20-degree bank				

Required Operation	Errors: Transfer Link	Errors: Transfer SNJ	Errors: Control SNJ	Criterion
Exercise 6: Steep Turns; Power-On and Power-Off Stalls				
when airspeed is 120 m.p.h.	5	1	6	±5 degrees
207. Brings nose to 3-point attitude (+7 degrees of pitch)	3	0	1	±5 degrees
208. Coordinates aileron and rudder	6	0	0	±½ ball
209. Gets definite break	0	1	1	yes or no
Part C-2: (recovery)				
210. Opens throttle smoothly	1	0	0	yes or no
211. Returns wings to level by the time airspeed is 100 m.p.h.	0	2	3	±5 degrees
212. Returns nose to level by the time airspeed is 100 m.p.h.	3	5	7	±5 degrees
TOTALS FOR PART C	22	12	22	
TOTALS FOR EXERCISE 6	**117**	**36**	**115**	