

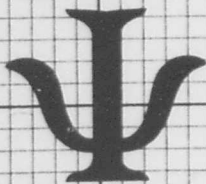
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The Forgetting of Instrument Flying Skills as a Function of the Level of Initial Proficiency

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PORT WASHINGTON, NEW YORK

THE FORGETTING OF INSTRUMENT FLYING SKILLS AS A FUNCTION
OF THE LEVEL OF INITIAL PROFICIENCY

Technical Report: NAVTRADEVGEN 71-16-18

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FOREWORD

PURPOSE

This experiment was designed to answer two questions:

1. How are instrument flying skills affected by a four-months interval of non-flying?
2. Does this effect differ as a function of initial level of flying proficiency, i.e. amount of initial training?

METHOD

After exposure to equal classroom training, two matched groups of ROTC students without previous flight instruction were given a "high" and an "intermediate" amount of OFT training respectively. Following a four-months period of non-flying (non-practice) they were tested for retention.

RESULTS

1. The four-months interval of non-practice resulted in considerable decrements in the "discrete procedural" aspects of flight. If these decrements occurred in actual flying situations they would have grave consequences for operational capability and safety.
2. As for the "continuous flight control" aspects of flight, forgetting occurred only occasionally and in amounts considered of little practical significance by the investigators.
3. The differential effect of non-practice on "procedural" versus "flight control tasks" was observed even where the two types of tasks were carried on simultaneously.
4. In most instances there was no relationship between amount forgotten and initial level of flying proficiency. That is, at the end of the four-months interval the "high initial training" group retained its superiority over the "intermediate initial training" group.

These results are similar to the findings of TR NAVTRADEVGEN 71-16-17, "Survey of Flying Proficiency Problems in the Naval Air Reserve Training Command" which showed that jet fighter pilots reported a greater number of forgetting incidents involving "procedural" rather than "flight control" tasks.

IMPLICATIONS

1. Programs directed toward the maintenance of flight proficiency should include ample practice and frequent evaluation of flight tasks of the procedural type.

2. Research is still needed before the following operationally important questions can be answered:

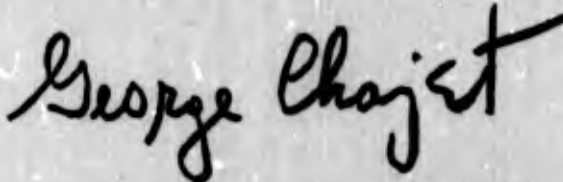
a. How much learning and review is needed for flight-control tasks, especially in order to maintain proficiency in more complex missions?

b. Should procedures be learned and reviewed in conjunction with flight-control tasks or separately?

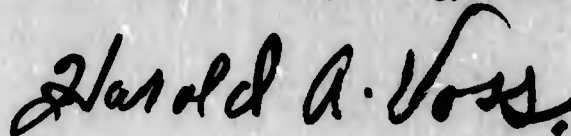
c. How should the trainees' time be apportioned among the various types of flight trainers?

The Aviation Psychology Division of the U. S. Naval Training Device Center is now conducting research which, in addition to other purposes, will help clarify these problems. One project is comparing the effectiveness of learning several aspects of flight proficiency separately versus together; another project is analyzing naval aircraft accident data and pilot opinion in order to provide the knowledge requisite to the improvement of flight training regimes. It will also determine whether pilot-related accidents are more related to the "procedural" rather than the "flight-control" aspects of flying proficiency.

GEORGE CHAJET
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BRIEF OF STUDY

A great deal of flight training proceeds in the interests of flying proficiency, and this includes both in-flight and Operational Flight Trainer (OFT) activity. The underlying assumption in flight training for the maintenance of flying proficiency is that certain aspects of flying skills are forgotten and this assumption is sound and unquestioned. However, the type and amount of flight training that is prescribed to meliorate the forgetting is largely based on intuitional guess-work, and has no foundation in objective research findings. Experimental psychology has generated a large body of research studies on the forgetting of human responses, but most of these investigations have been conducted within the context of simple laboratory verbal and motor skills and cannot, without empirical corroboration, be generalized to the multiplicity of activities that comprise flying.

The principal experimental variable in the experiment was the level of proficiency in the SNJ OFT prior to a four months' retention interval of non-flying. Following a four-hour academic training program in instrument flying, two groups of ROTC students of the University of Illinois were trained in the SNJ OFT. One group was given five training trials and the other group was given ten trials, representing intermediate and high levels of proficiency in the trainer, respectively. Each trial was about fifty minutes in length and was an extensive series of maneuvers and procedures from takeoff to landing. All trials were under-the-hood instrument flights. Following the final training trial, the four months' retention interval was interpolated. The retention tests consisted of four additional trials, each identical to the training trials. Analysis of the data emphasized the differential forgetting of procedural and flight control responses, the two main response categories in instrument flying.

A summary of the findings is as follows:

1. Discrete procedural responses are more susceptible to forgetting than continuous flight control responses. The

amount of forgetting was statistically significant for all classes of procedures analyzed, whereas proficiency in controlling flight parameters (bank, altitude, airspeed, etc.) demonstrated only selective forgetting decrements in statistically significant amounts. Important for operational flight training is that the absolute amounts of forgetting for flight parameters were judged to be practically insignificant, whereas the amount of procedural forgetting was of considerable practical importance.

2. Both groups showed similar amounts of forgetting for most measures of flying proficiency. This meant that the group with the greatest amount of initial training had the highest performance level after the retention interval.

3. The number of trials taken to relearn to the level of the proficiency attained on the final training trial is fewer than that taken originally.

4. The number of trials taken to relearn is a positive function of the amount of initial training.

Certain similarities were found between the findings of this study and those using relatively simple procedural and tracking tasks as laboratory research devices. One difference noted was that the relatively complex OFT requires a much longer time to relearn than when simple tasks are used, showing that task complexity is a variable in forgetting.

The principal implication of this research for operational flight training is that procedures deserve primary emphasis in programs directed toward the maintenance of flying proficiency. Many procedures can be taught in a classroom with simple training aids, but others can profitably use either a cockpit procedures trainer, a general instrument flight trainer, or an OFT. An OFT is the most versatile training device but it has drawbacks of high initial and maintaining costs. When an OFT is not feasible for a program, a combination of a general instrument flight trainer and a cockpit procedures trainer should be considered.

DETAILS OF THE STUDY*

INTRODUCTION

A considerable portion of military flying is subsumed under "proficiency flying" and is predicated on the belief that forgetting of flying skills ensues during periods of non-practice and that a certain amount of periodic flying is necessary to maintain an acceptable level of proficiency. This belief hardly can be questioned because it is secured in the data of experimental psychology and is well-grounded in the practical, day-to-day experiences of pilots. Yet, even though laboratory research and practical experience document the existence of forgetting, neither of these sources of information are complete enough to specify the characteristics of a flying proficiency program. At present there is little objective data on the rate and amount of forgetting of the several response classes that comprise flying, or on the requirements to re-train to the level of proficiency held immediately prior to the retention interval. If these data were available, amounts and types of flying could be specified to maintain proficiency in the most economical manner. Also, the optimum type of flight trainer for a particular class of aircraft, as well as use of the trainer, could be best specified. Currently the relative contributions of general instrument trainers, cockpit procedures trainers, and OFT's to the maintenance of flying proficiency is controversial. No one can state, with the authority of research data to back his statement, that any single

*Mr. Robert F. Mengelkoch was Project Leader for this study and was responsible for the development of experimental materials, as well as the collection and statistical analysis of the data. The appendices of this report present the details of the experimental procedures and the data, and were prepared by Mr. Mengelkoch. Dr. Jack A. Adams was Principal Investigator for Contract N6 1339-126 and was responsible for interpreting the data and writing the main body of the report. Mr. Charles A. Gainer assisted in data collection and analysis.

one of these instruments or a combination of them can give the greatest training advantage per unit of cost.

Human engineers also can make important uses of data on the forgetting of flying skills when they are called upon to assist in the design of flight training equipment and flight training programs. By knowing what flying skills are most readily forgotten, it would be possible to give flight training equipment and flight training programs the appropriate emphasis to compensate for most expected and serious losses in proficiency due to forgetting.

As a result of our lack of sound scientific knowledge of forgetting, the organization of flying proficiency programs, as well as aspects of the design and use of flight training devices, have been based on intuition derived mainly from the cumulated experiences of pilots. Without discounting the keenness of intuition that can develop within the context of practical experience, it is axiomatic that intuitional approaches are highly fallible and can result in inadequate or unnecessarily expensive modes of operation. Only objective research data on the retention of response classes required in flying can be a substantial basis for decisions on these matters. This report is directed towards the need for objective data on the forgetting of flying skills. The forgetting of instrument flying skills was studied as a function of two levels of initial flying proficiency.

A study of the retention of flying skills has the same formal paradigm as any laboratory study of forgetting but is more complicated because of the multiplicity of responses that must be observed and measured. Basically, flying can be considered as having two classes of responses: visual-motor tracking and procedural. A visual-motor tracking response is defined as a continuous response to a continuous stimulus, and the smooth motor control of limb displacements is a prominent aspect of tracking. In instrument flying several display stimulus sources must be tracked at any moment. Examples are holding a particular heading, airspeed, altitude, bank, pitch, rate of turn, rate of climb, etc. In contact flying tracking responses are, of course, made to cues outside the cockpit in addition to those on the instrument panel. Procedural responses, on the other hand, can be conceived as mediating responses

elicited by environmental cues which have a selective function for overt responses. The occurrence of a mediating response results in a response-produced stimulus complex which in turn is an important determiner of overt responding (4, 9). Presumably any class of overt responses can receive guidance from mediating responses. Essentially, procedural responses are nothing more than knowing the steps in a sequence and the order (if any) of occurrence required for these steps. Each step in the sequence is a matter of selecting a possibility for the overt response from among a number of possible choices. The eliciting cues for procedural responses may be external to the cockpit such as approach procedures in a contact landing, internal to the cockpit such as response to a fire warning light, auditory as when an engine suddenly fails, or bodily when an engine fails and the pilot senses a loss of lift. Many times combinations of these cues are present. Procedural responses are overtly manifested in flying in three basic ways:

1. Relatively discrete motor responses. Examples are positioning switches, knobs, levers, etc. Knowing when and how much to adjust the throttle under a particular set of flight circumstances is a case of procedural responses revealed by a discrete motor response.

2. Verbal responses. Ordinarily for the pilot this is communication with the ground, although it also could be with other aircraft or with aircrew members within the same aircraft. Flying involves a number of defined, stereotyped radio communications and all pilots must know these voice procedures.

3. The timing of changes in a tracking response sequence. Here procedural responses are intermediate, mediating acts to guide different tracking sequences in a maneuver. An example of procedural responses cueing several tracking sequences is knowing that a standard procedure turn to go from outbound to inbound ILS tracking on an instrument approach involves a forty-five degree right turn, a one-minute leg on the new heading, a one-hundred eighty degree left turn, and tracking of the new heading

until the ILS beam is intersected. The actual accomplishment of each of these steps is dependent primarily on the proficiency of tracking responses, but whether or not the steps are initiated in the first place depends on the pilot's proficiency in procedures, i. e., in knowing the sequential stages of a standard procedure turn.

Another complexity consideration for the pilot's flight task is that procedural responses may be required concurrently with tracking responses, such as an in-flight emergency where a procedural sequence must be carried out while, at the same time, maintaining a safe attitude of the aircraft. Or, procedural responses may be required independently of tracking, such as for the normal procedures required in starting an aircraft. Research on the retention of flying skills poses the need to examine the forgetting of tracking and procedural responses within the context of the complex flying task itself. Each of these response classes separately considered in a simple task context may show quite different forgetting characteristics than when they are both in a complex task and may be required in a concurrent, time-shared relationship with each other.

A large number of studies have been conducted on forgetting since the first objective experiments of Ebbinghaus in the 19th century, and a majority of them have used simple verbal learning tasks. Recently more attention has been directed to the forgetting of the classes of perceptual-motor responses important for flying, although each class has been studied singly with simple tasks. A recent and comprehensive report (1) presented two major retention studies, one for responses in a procedural task and the other for responses in a compensatory tracking task. The experimental variables were the length of the retention interval (up to two years) and two amounts of initial practice. For both tasks the amount of retention loss increased as a function of the length of the retention interval. Over a two-year interval a highly trained group on the procedural task had a loss of almost one-hundred per cent while a group with a relatively small amount of initial training had about sixty per cent loss. The per cent retention loss for the tracking task was not so clearly a function of the amount of initial training,

being at a maximum of about twenty per cent over two years for both amounts of initial training. For both the procedural and tracking task, the amount of practice required to retrain to the original level of proficiency was a positive function of the amount of initial practice and the length of the retention interval, and was less than that taken to train originally. Of interest for aviation is the finding that forgetting of procedural responses is greater than tracking responses. The marked forgetting of procedural responses is consistent with the findings of an earlier study (7).

The investigation to be reported here did not involve actual air training and testing but the research studies (3, 6, 8, 12, 13) which show positive transfer to flying an aircraft from practice in a flight trainer are solid grounds for assuming many common response elements between an OFT and its parent aircraft. While not denying the ultimate research necessity of validating laboratory findings in the air, it is believed that results on forgetting obtained with an OFT as the research device have some generality to problems of maintaining in-the-air flying proficiency.

EXPERIMENTAL METHOD

Experimental Design

The experimental design used two groups of subjects and the SNJ OFT (Link 1-CA-2) as the research device. Following a four-hour academic training program and one familiarization trial in the trainer, one group (Group 5) was given five training trials and the other group (Group 10) was given ten training trials, representing intermediate and high levels of proficiency in the trainer, respectively. A retention interval of four months was then interpolated after the last training trial for both groups. The retention tests consisted of four additional trials. Retention trials were identical to training trials. Each trial was a structured 50-minute mission of maneuvers and procedures from starting the engine and takeoff to landing and shutdown of the engine. All trials were under-the-hood instrument flights. The initial subgroup of subjects began academic training in October 1957, and the testing

of the final subject was completed June 1958.

Research Equipment

The experimental apparatus used in this study was the Link 1-CA-2 Trainer designed to simulate the SNJ aircraft (SNJ OFT). An external view of the trainer is shown in Figure 1. The trainer was used in its standard configuration except for two modifications:

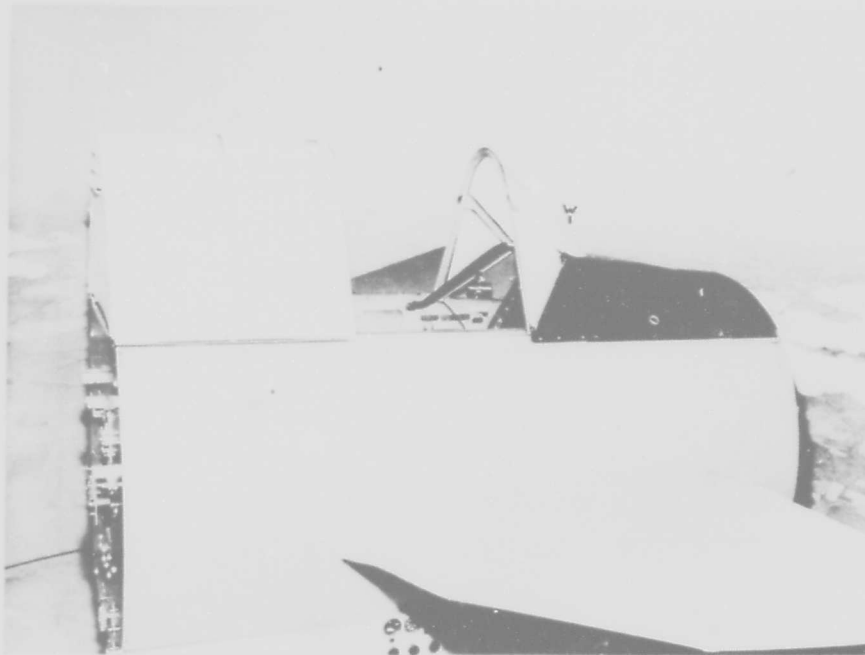


Figure 1. The SNJ Operational Flight Trainer.

1. The rudder control was disconnected so that the turning rate of the trainer was controlled entirely by the degree of bank established by aileron stick movement. The use of the rudder in a turn is a low fidelity aspect of the SNJ OFT because it requires a constant input throughout a turn. This is in contrast to the SNJ aircraft where the appropriate input to aileron and rudder can be made for the desired rate of turn and the controls can then be neutralized and the aircraft flies itself through a coordinated turn with no further aileron and rudder action by the pilot (assuming

no perturbing effects such as turbulence). This modification of the trainer gave it the same flight characteristics as those aircraft which have a linkage of aileron and rudder and only an aileron stick movement is required for a turn, or jet aircraft where the rudder is almost never used in air work.

2. The instrument panel was re-designed to emphasize those flight and engine instruments necessary for the maneuvers and procedures used. There were two red warning lights on the panel, one for each emergency used in the study. The modified panel is shown in Figure 2.

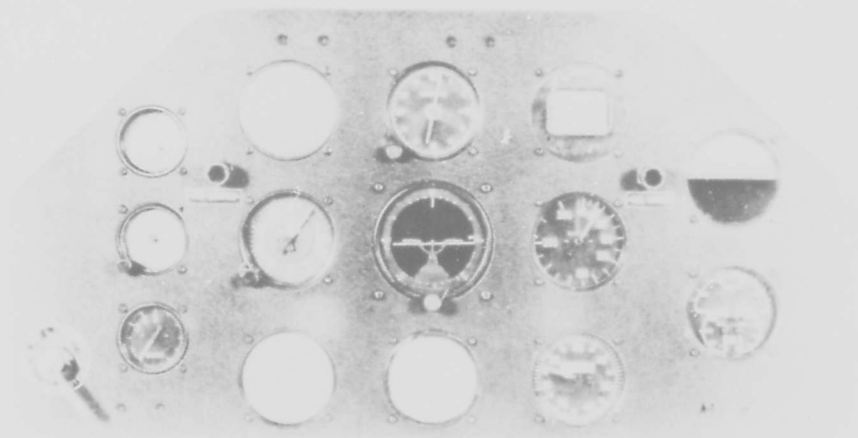


Figure 2. Modified instrument panel for the SNJ OFT.

For the scoring of subject performance, the trainer was wired so that all necessary flight and engine instrument information, and the positions of all discrete controls, appeared on a repeater console at the experimenter's desk. This console is shown in Figure 3. All flight and engine instruments of the cockpit of the trainer were repeated directly with the exception of the attitude indicator which is a two-dimensional instrument that does not allow for easy and objective performance recording. In the case of the attitude instrument,

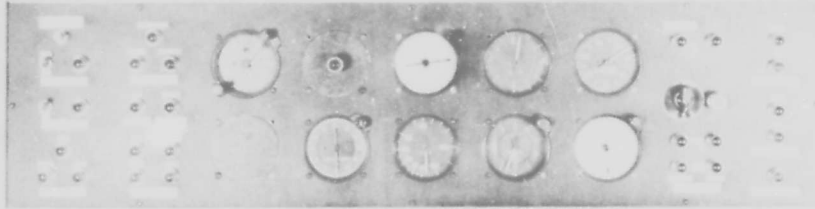


Figure 3. The repeater console used by the experimenter for performance recording.

the two dimensions were represented on the repeater console by two scaled dials, one for pitch and one for bank. Each procedural control had a red light on the console which informed the experimenter at all times of the control position in the cockpit.

In any study of forgetting it is methodologically important that the stimulus display for the subject be known and controlled. For this reason all trials were "under-the-hood" instrument flights. If the trainer had been used in a pseudo-contact configuration where the subject could view the cyclorama surrounding the trainer as well as the cockpit instrument display, the source of visual cues to which the subject would be responding would never be known unequivocally. Since there is some likelihood that the amount of forgetting may be a function of the type and informational content of the cues involved, it was considered an important experimental control to limit the cues to the cockpit only. The forgetting of contact flying skills is a sufficiently complex topic to warrant separate investigation. Therefore, the canopy of the trainer was covered with white paper so that, with the canopy closed it was impossible to see out of the trainer. The white paper allowed some illumination from the overhead lights to enter the cockpit, but two directional lights also were placed on either side of the cockpit to

insure adequate illumination of the instrument panel. Ventilation was provided by a blower utilizing a ventilating duct in the floor of the trainer. A two-way intercom system was employed which provided clear voice communication between experimenter and subject.

To insure comparable day-to-day operating characteristics, the trainer was thoroughly preflighted every working day. A preflight sheet was devised for systematically checking all pertinent items. Any discrepancies were noted and immediate adjustments were made.

Flight Training Methods

Academic training. Because the subjects of this experiment were naive to flying, it was considered necessary to give them classroom training in the principles of SNJ flight. Two experimenters conducted each session. All subjects were given the same ground training consisting of two sessions of two hours each. Subgroups of four or five subjects were in ground training at any one time. The use of small subgroups insured that trainer trials could begin immediately at the completion of academic training. If all subjects had been given academic training together some would have had to wait an inordinately long time to begin in the trainer and the forgetting of material presented in academic training undoubtedly would have been reflected in their performance in the trainer.

The curriculum of the first academic session included:

1. Brief introductory statement on the nature of the experiment.
2. Movie on the use of flight controls.
3. Discussion and demonstration of the attitude indicator, heading indicator, altimeter, airspeed indicator, and manifold pressure gauge. These instruments were arrayed on a panel and the indicators on each instrument could be manipulated from the rear to present the instrument readings for various flight conditions.
4. Movie on attitude instrument flying.
5. Discussion of attitude instrument flying.
6. Demonstration and explanation of the flight instruments in relation to the basic maneuvers in instrument flying.
7. Definitions pertinent to aircraft maneuvering.

The curriculum of the second session was of four parts:

1. Acquaintance with the procedural sequences to be learned. There were twelve procedures checklists to be learned and each was printed on a large card for classroom use.

2. The location of controls was demonstrated and practiced in a full-scale photographic mock-up of the SNJ cockpit. With the exception of a modified instrument panel, this photographic mock-up was the same as used in previous research of the Aviation Psychology Laboratory (2) where it was found that this method of practicing procedures benefited subsequent performance in the SNJ aircraft.

3. Written examinations on the procedures checklists and on flight conditions represented by various values set in the panel array of flight instruments. These examinations were not scored but were a learning device for the benefit of the subjects. After the subjects had written down their answers the correct answers were given and discussed.

Appendix A gives a detailed account of the academic training methods, including photographs of the SNJ photographic cockpit and the instrument panel array.

Familiarization trial. Preliminary experimentation indicated that it was necessary to give a subject a familiarization period in the SNJ OFT before the actual scored training trials were begun. For a naive subject the flying task is of such complexity that the grossness of his errors on the very first time in the trainer precludes meaningful response measurement. After one trial the subject is sufficiently acquainted with the cockpit layout and techniques of trainer control to allow the scoring of his performance.

The familiarization trial began with the experimenter pointing out all pertinent controls and instruments in the cockpit and going through the first four procedural checklists (see Appendix A). This was done with the subject seated in the cockpit and the experimenter standing alongside the trainer. The subject was then put under the hood for the remainder of the trial and instruction proceeded over the inter-com system. The familiarization period was identical in format to the

training and retention trials except that the experimenter verbalized in expanded detail each maneuver and procedural sequence, telling the subject what to do at each stage of the mission and the nature of his errors after he had completed a stage.

Because of the complexity of the task for a naive subject, two reference cards were taped on the instrument panel as additional aids. One card gave the degree of bank required to make a standard rate turn at the three basic airspeeds used. This card is shown in Table 1. The other card is shown in Table 2, and provides certain basic procedural information. The two cards were on the panel throughout the entire experiment. During the course of the research the experimenters measured a sufficient number of errors associated with the information on these cards to suggest that subjects often were too preoccupied with the flight task to fully benefit from these aids.

TABLE 1

Reference card placed on instrument panel

<u>Standard Rate Turn</u>	
90 MPH	15° bank
110 MPH	15° bank
140 MPH	20° bank

TABLE 2

Reference card placed on instrument panel

<u>CONDITION</u>	<u>THROTTLE</u>	<u>RPM</u>	<u>MIXTURE</u>	<u>GEAR</u>	<u>FLAPS</u>	<u>A/S</u>
Take Off	36"	High	Full Rich	Down	Up	90
Climb	30"	High	Full Rich	Up	Up	110
Cruise	26"	Cruise	Cruise	Up	Up	140
Slow Flight	22"	High	Full Rich	Down	Down	90
Descending Turn	10"	High	Full Rich	Down	Down	90
Glide	10"	Cruise	Cruise	Up	Up	110
Final Approach	15"	High	Full Rich	Down	Down	90

Training and retention trials. Following the familiarization period in the trainer, the performance-for-record trials were begun. After the final training trial both groups were given a retention interval of four months, followed by four retention trials. Pre-experimental testing demonstrated that four retention trials were sufficient for most measures to regain the level of proficiency held on the final training trial.

As the subject completed each procedural sequence and/or maneuver, immediate knowledge of results was given. This included a once-through review of errors committed and what the correct responses should have been. Improper flight performance (such as overcontrolling) was called to the subject's attention after a maneuver and methods of improvement were suggested.

Every effort was made to schedule each subject at least twice a week to minimize the forgetting between trials, and no oftener than once a day to minimize possible fatigue effects. Because of subject cancellations and temporary trainer malfunctions, the scheduling goal was not entirely achieved. On the other hand, the actual mean time interval between each of the training and retention trials is not considered detrimental nor sufficiently different between Groups 5 and 10 to be a contributory influence on the results. The average number of days between trials is presented in Table 3.

TABLE 3

Mean number of days between training and retention trials, and mean number of days in the retention interval

<u>Group</u>	<u>Days Between Training Trials</u>	<u>Retention Interval</u>	<u>Days Between Retention Trials</u>
5	4.1	121.2	2.6
10	3.1	121.5	2.5

The Flight Task

All trials were identical, each consisting of a mission that was designed to sample as many of the common maneuvers and procedures encountered in a typical aircraft instrument flight that could be simulated in the SNJ OFT. The sequence of the mission was: cockpit check, engine starting procedure, engine run-up check, takeoff checklist, actual takeoff, 180-degree left climbing turn, 180-degree right climbing turn, level off at 5000 feet, straight and level leg, change to slow flight, 360-degree descending right turn (2000-foot loss of altitude), change to normal cruise, glide to 1000 feet, landing checkoff list, procedure turn, final approach, and two emergency procedures (prop overspeed and fuel warning) that were interpolated at any of five points during the flight. Table 4 indicates the emergency presentation schedule. The flight task is presented pictorially in Figure 4.

TABLE 4

Schedule for presentation of the two emergency procedures, prop overspeed (PO) and fuel warning (FW)

LOCATION	Training trials										Retention trials			
	1	2	3	4	5	6	7	8	9	10	1	2	3	4
After level-off		PO	FW			PO				FW		FW		PO
After straight and level leg	FW				PO			FW	PO				FW	
After low visibility turn				PO	FW		FW			PO	PO			
After change to normal cruise	PO	FW				FW		PO				PO		FW
After glide				PO	FW		PO		FW		FW		PO	

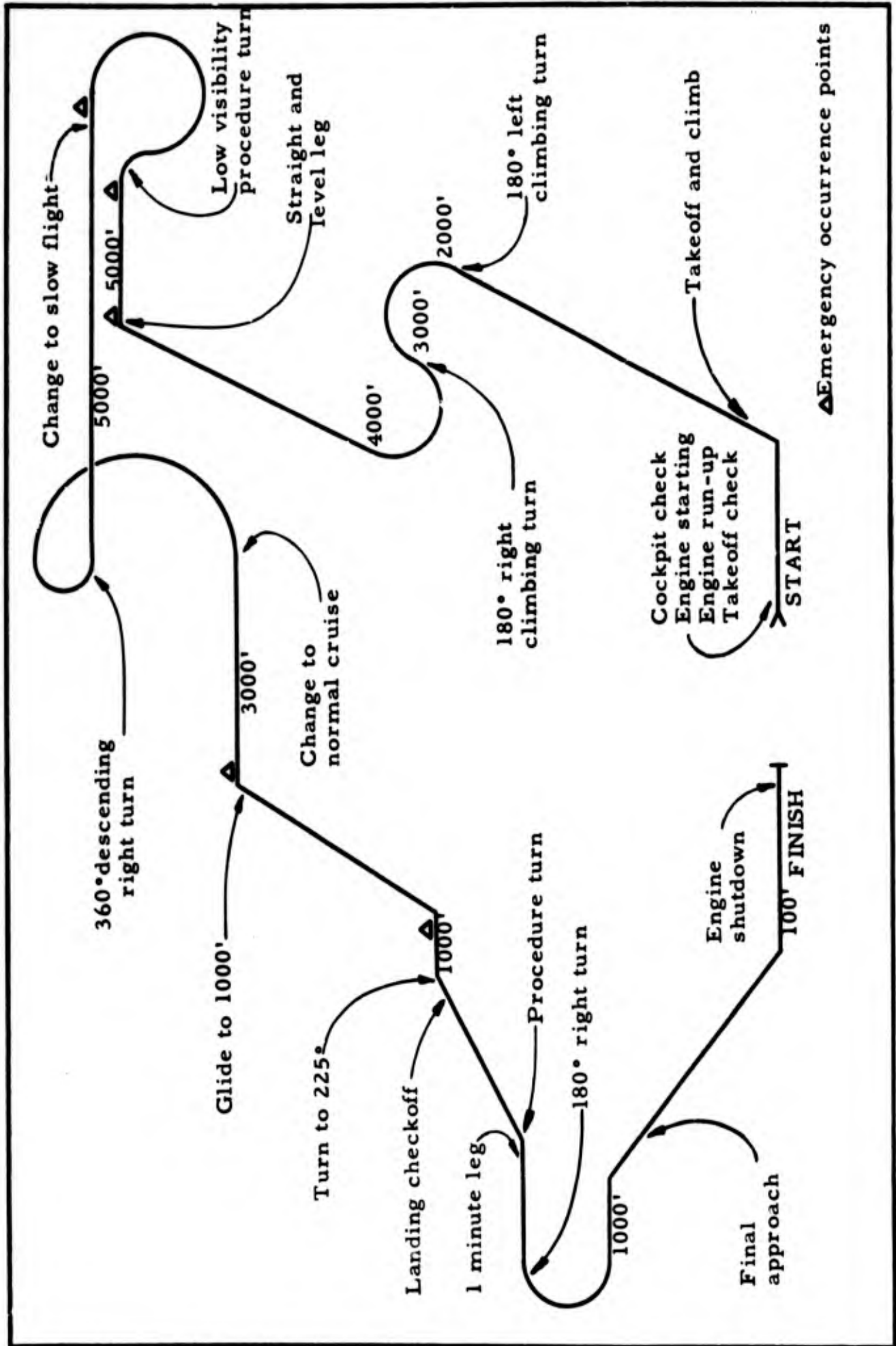


Figure 4. Mission sequence. This same mission was used on every trial.

The cockpit check, engine starting procedure, engine run-up check, and the takeoff checklist were performed with the canopy open. These four procedural sequences were directly observed and scored by the experimenter standing alongside the trainer. All other maneuvers were performed with the canopy closed and were scored from the repeater console. The flight task was designed to take 50 minutes, but usually took somewhat longer in the early trials when flying proficiency was low. Instructions were given at the beginning of each maneuver and were read verbatim from typewritten cards. The standardized instructions are presented in Appendix B.

Performance Recording

A subject's performance on each trial was recorded on a set of 15 scoring sheets. These sheets are reproduced in Appendix C. The rules of scoring appear in Appendix D.

Flight parameters. Proficiency in flight control (accuracy of multidimensional tracking) is revealed in the extent to which basic flight instruments are kept aligned with a value defined as ideal for a particular maneuver. The primary flight parameters recorded were altitude, airspeed, bank, and heading, and each was scored in terms of error deviation from an Index of Desired Performance each time the experimenter observed a signal light on his console which flashed at ten-second intervals. This method gave several measures for each relevant parameter on a maneuver. Summary indices of proficiency by this technique of measurement would be expected to have greater reliability than conventional methods of pilot proficiency measurement which have used only a single measure of maximum error deviation for a parameter on a maneuver (5, 10).

The heading data were not used in the analysis because heading values were insensitive to small changes in bank. This was a result of certain inadequacies in the computational equipment of the OFT. Adjustment of the trainer to provide proper relationships between degree of bank and airspeed in executing a standard rate turn resulted in an insensitivity (damping) of the heading indicator for small changes in bank. Therefore, the heading parameter was not considered particularly

meaningful and was not used. One exception to the shortcomings in heading data was the roll-out heading error at the completion of a maneuver that required a heading change. These values were found to be meaningful indices of flying proficiency and are included in the analysis. Another measure of proficiency in terminating a maneuver was the level-off error in altitude when the maneuver required transition from one altitude level to another.

Procedures. There was a total of 125 procedural items which were scored on an error--no error basis. An error in procedures was scored if the item was either omitted, performed wrong, or occurred out of place in the sequence (providing that position in the sequence happened to be important for that item). In addition to performing the discrete items of an emergency procedure correctly, it is often necessary to achieve specific values for certain flight parameters as an integral part of successfully correcting the emergency state. For the prop overspeed and fuel warning emergencies used in this study it was required that the subject establish an airspeed of 110 MPH and lose a minimum amount of altitude. Also, it is desirable that an emergency be corrected in the minimum amount of time. Therefore, minimum airspeed achieved, amount of altitude lost, and time to complete the sequence were recorded as values related to proficiency in emergency procedures.

Subjects

Thirty-three University of Illinois ROTC male undergraduate students participated in the study. ROTC students were used because they were believed to be physically and intellectually more equivalent to the military pilot-officer population than a random sample from the university male student body. All were volunteers and were selected with the restriction that they had no plans to enter a private or military flight training program during the coming year. One dollar was paid for each hour of participation.

Four of these subjects were used in pre-experimental testing for the purpose of refining training and scoring methods. They were run through the entire experiment, including the four months' retention interval and the retention trials.

The remaining 29 subjects served in the main experiment. Three of these completed the training trials but were unavailable for the retention trials, leaving a total of 26 subjects in the experiment--13 in each group.

All subjects were naive to flying, their only acquaintance being an occasional ride as a passenger in a commercial, military, or light airplane. Although the initial training flights would have been greatly facilitated if subjects with some flying experience, such as private pilots, were used, the final decision was to use naive subjects. The determining factor for this decision is the problem of controlling intervening activity that would influence the retention test trials. If private pilots were used as subjects, there would be some likelihood that they would participate in light plane pleasure flying during the retention interval. Because Air Force research (11) has shown that light plane flying has a positive transfer effect to the T-6 (SNJ) aircraft, it would be reasonable to expect that pleasure flying in the retention interval might transfer positively to the SNJ OFT, thereby contaminating the entire experiment. To avoid this, the added difficulties of training naive subjects were undertaken.

Experimenters

Two experimenters were used. Both were staff members of the Aviation Psychology Laboratory, University of Illinois, and both were ex-military pilots.

RESULTS

Method of Data Analysis

Flight parameters. At each ten-second interval throughout a maneuver the error deviation from an Index of Desired Performance was recorded for each relevant flight parameter. The basic measure of skill for each subject in controlling a flight parameter on a maneuver was the mean absolute error deviation. These means for a subject were averaged over all maneuvers involving the parameter to obtain an overall measure of his proficiency on a trial.

Procedures. The score for a subject on a particular procedural sequence was the number of items wrong. The individual procedural sequences were grouped into four basic categories and a subject's score for the category on a trial was the sum of the scores for the individual procedural sequences comprising the category. The four categories were:

1. Static procedures. No flight control of the OFT was required when these procedures were performed. Number of items: 57.

2. Dynamic procedures. Flight control was required concurrently with the performance of the procedure. Number of items: 47.

3. Emergency procedures. Concurrent flight control was required and the cues for the emergency were presented without warning. Number of items: 21.

4. All procedures. The procedural items of the above three categories combined. Number of items: 125.

Three other measures of proficiency in emergency procedures recorded were minimum airspeed achieved, amount of altitude lost, and time to complete the emergency sequence. A subject's score on a trial for each of these measures was the mean of the two values obtained on the two emergency sequences.

Computation of per cent retention loss. Because procedures are discrete error--no error items, the computation of per cent retention loss was computed somewhat differently for procedures than for other measures. For procedures, the following formula was used:

$$\text{Per cent Retention Loss} = \frac{\left(\begin{array}{c} \text{Mean error on} \\ \text{1st} \\ \text{retention trial} \end{array} \right) - \left(\begin{array}{c} \text{Mean error on} \\ \text{final} \\ \text{training trial} \end{array} \right)}{\text{Total possible number of errors}} \times 100$$

In the case of all other measures, it was not possible to express total possible errors for the denominator as in the above formula for procedures. Therefore, the following formula, which is essentially

the same as that used by Ammons et al. (1), was used:

$$\text{Per cent Retention Loss} = \frac{\left(\begin{array}{c} \text{Mean value on} \\ \text{1st} \\ \text{retention trial} \end{array} \right) - \left(\begin{array}{c} \text{Mean value on} \\ \text{final} \\ \text{training trial} \end{array} \right)}{\left(\begin{array}{c} \text{Mean value on} \\ \text{1st} \\ \text{training trial} \end{array} \right) - \left(\begin{array}{c} \text{Mean value on} \\ \text{final} \\ \text{training trial} \end{array} \right)} \times 100$$

The denominator is the amount learned in the training trials and the numerator is the amount lost over the retention interval. The weakness of this formula is that the denominator underestimates the true amount learned by some unknown amount, which in turn functions to overestimate the per cent retention loss. With error as the measure, the value on the first training trial is less than the maximum possible value because of academic training and the familiarization trial, and the value on the last training trial is greater than the minimum possible value because the learning curve has not been carried to its asymptote. Thus, the range of the two values comprising the denominator is reduced and per cent retention loss is overestimated. In contrast, the denominator in the formula for procedures is always maximum possible error and is not dependent on the range of learning obtained in the training trials. Recognizing that there is no completely satisfactory method of computing per cent retention loss for continuous measures, per cent retention loss values for them are nevertheless presented as indications of relative trends.

Statistical analysis. All statistical tests were performed on raw scores. The coefficient of risk is .05.

Initial Comparability of Groups

The scores on Trial 1 were obtained prior to differential experimental treatment and statistical comparison of them would indicate the initial equivalence of the two groups. For each measure, a t test was made of the null hypothesis for the mean difference between groups. None of the tests were significant, indicating that the two groups can be regarded equivalent in average ability.

General Observations

Considering the complexity of the flying task assigned to the subjects, and considering that subjects initially were naive with respect to flying, one problem was to employ training techniques that would result in satisfactory levels of skill within the training time available. To accomplish this goal, the best-known flight training methods were used: a well-organized academic training program, a full-scale photographic cockpit mock-up found effective in previous research (2) for the teaching of procedures, a familiarization trial in the trainer under close guidance of the experimenter, and complete knowledge of results after each maneuver or procedural sequence. As examination of subsequent tables and figures will show, the training was indeed effective. Group 10 was intended to be a high proficiency group and the levels of its mean errors on Trial 10 (final training trial before the four months' retention interval) for flight parameters and procedures were very low, indicating that they acquired high skill in flying the simulated SNJ aircraft. To illustrate, Group 10 on Training Trial 10 missed only 3.9 per cent of 125 procedural items, had 1.1 degrees of mean error in controlling the trainer in bank, 32 feet mean altitude error, and 2.3 MPH mean error in controlling airspeed. Observation of the subjects of Group 10 revealed that they had acquired smooth, coordinated control of the trainer and that procedural sequences were performed positively and almost error-free. Certainly this is impressive performance after only 15 hours of flight training, of which 4 hours were academic training. Group 5 had half the number of training trials given Group 10 and attained a satisfactory intermediate level of proficiency.

Retention of Procedures

Learning of procedures. Figures 5 - 8 show the original learning and retention curves for the four categories of procedures, with per cent correct as the response measure. The acquisition of procedural response sequences in the training trials follows a negatively accelerated trend characteristic of much of human learning data. Examination of Figures 5 - 8 shows that the form and level of acquisition curves do not differ importantly among the four categories of procedures. The values on

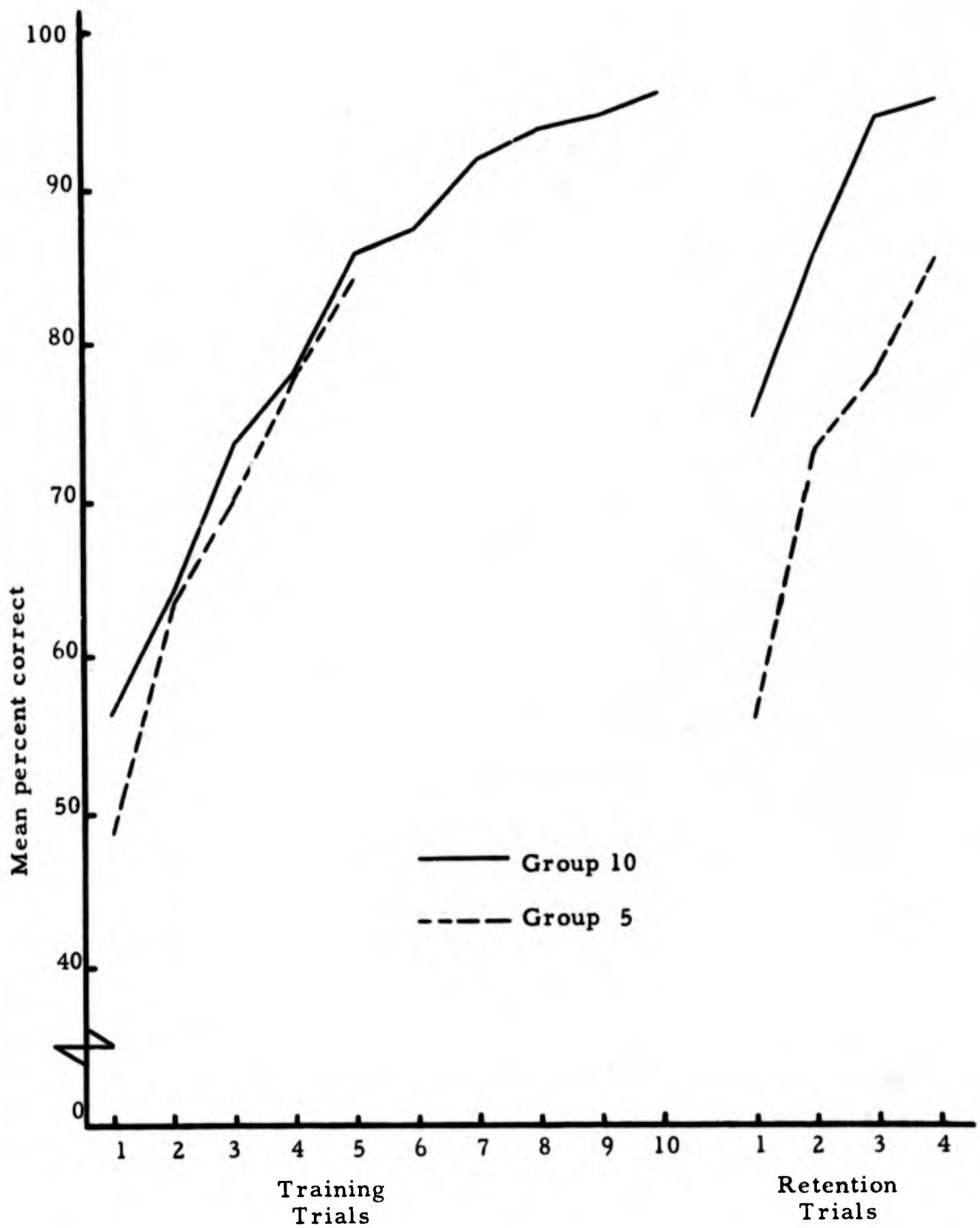


Figure 5. Performance on static procedures.

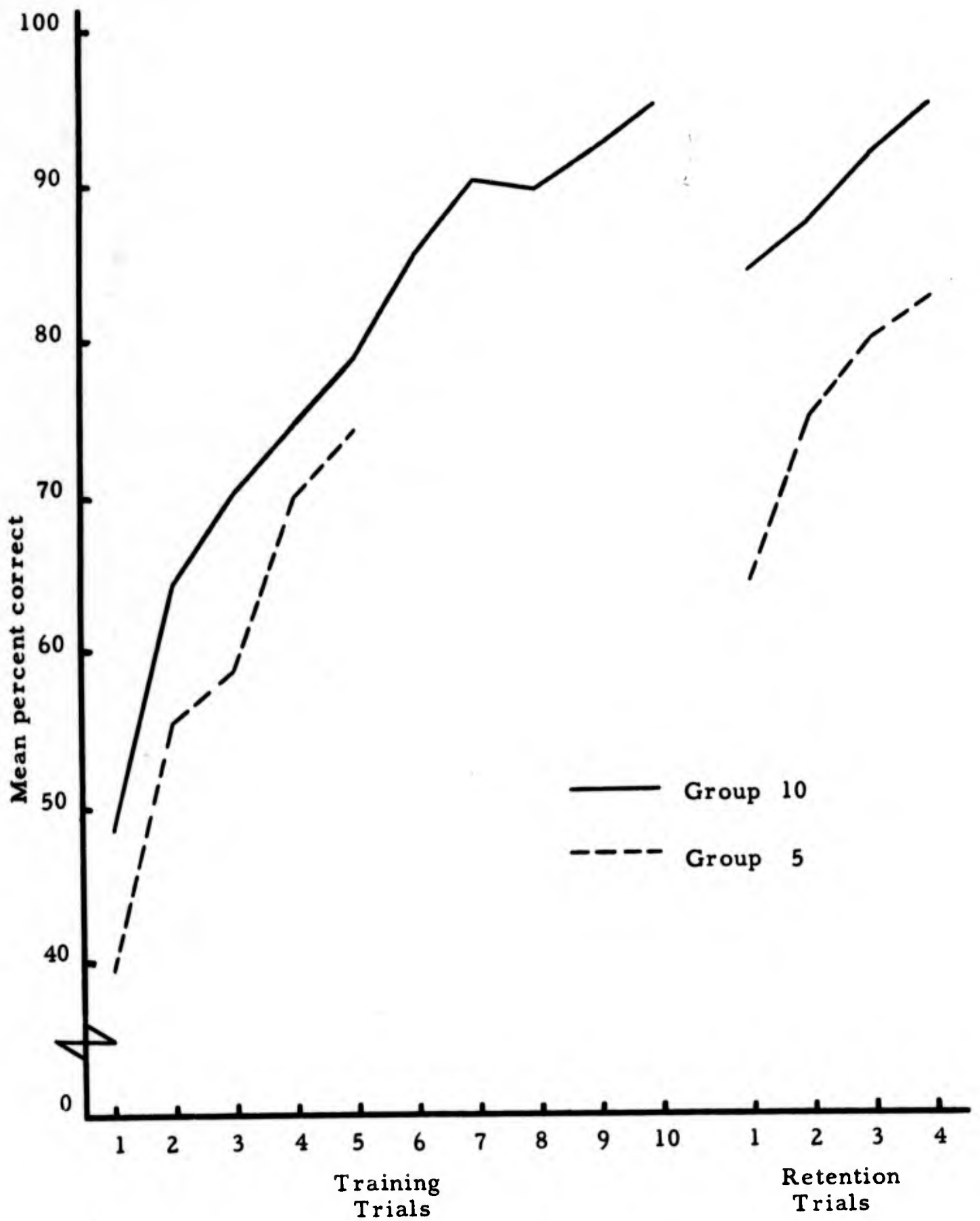


Figure 6. Performance on dynamic procedures.

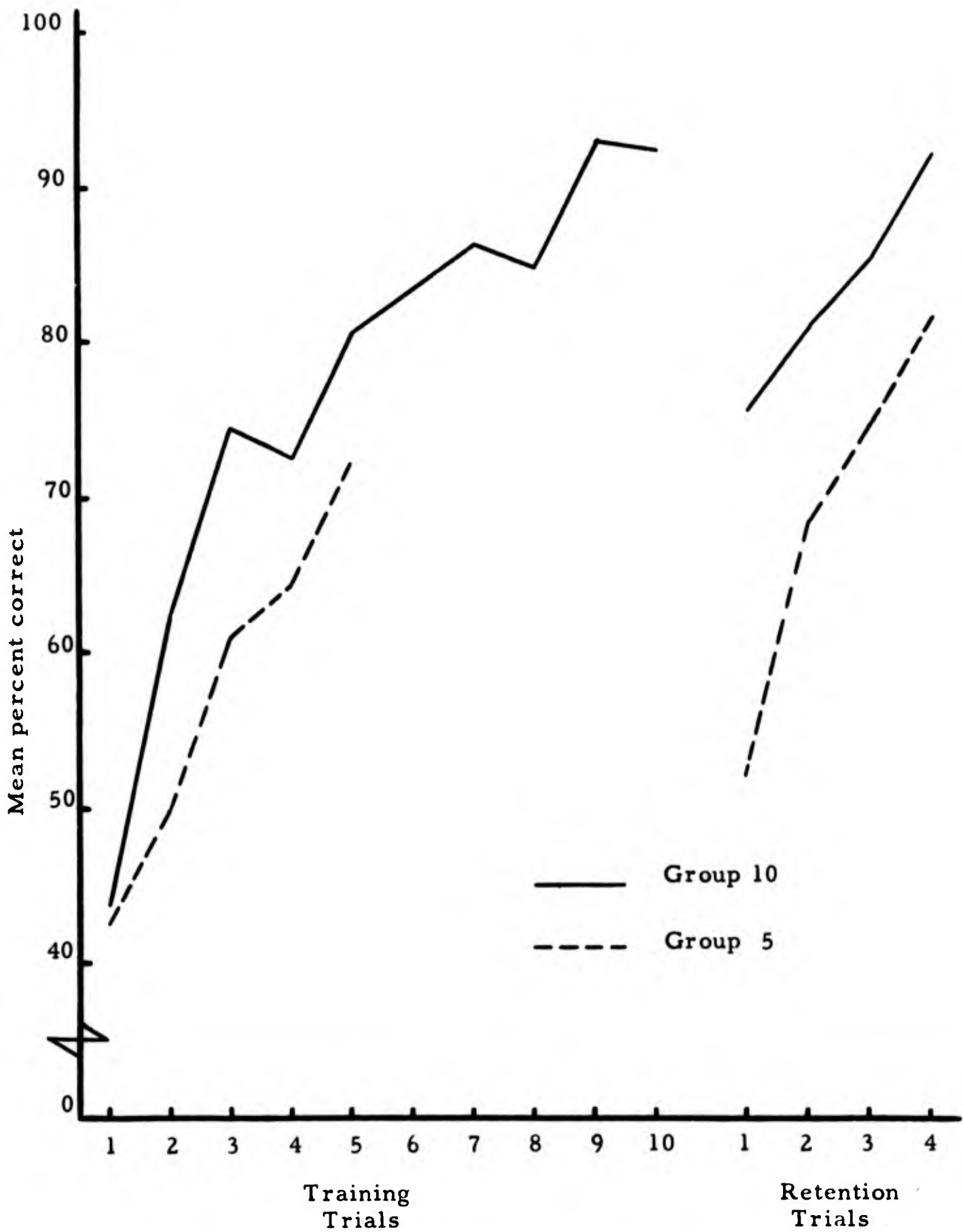


Figure 7. Performance on emergency procedures.

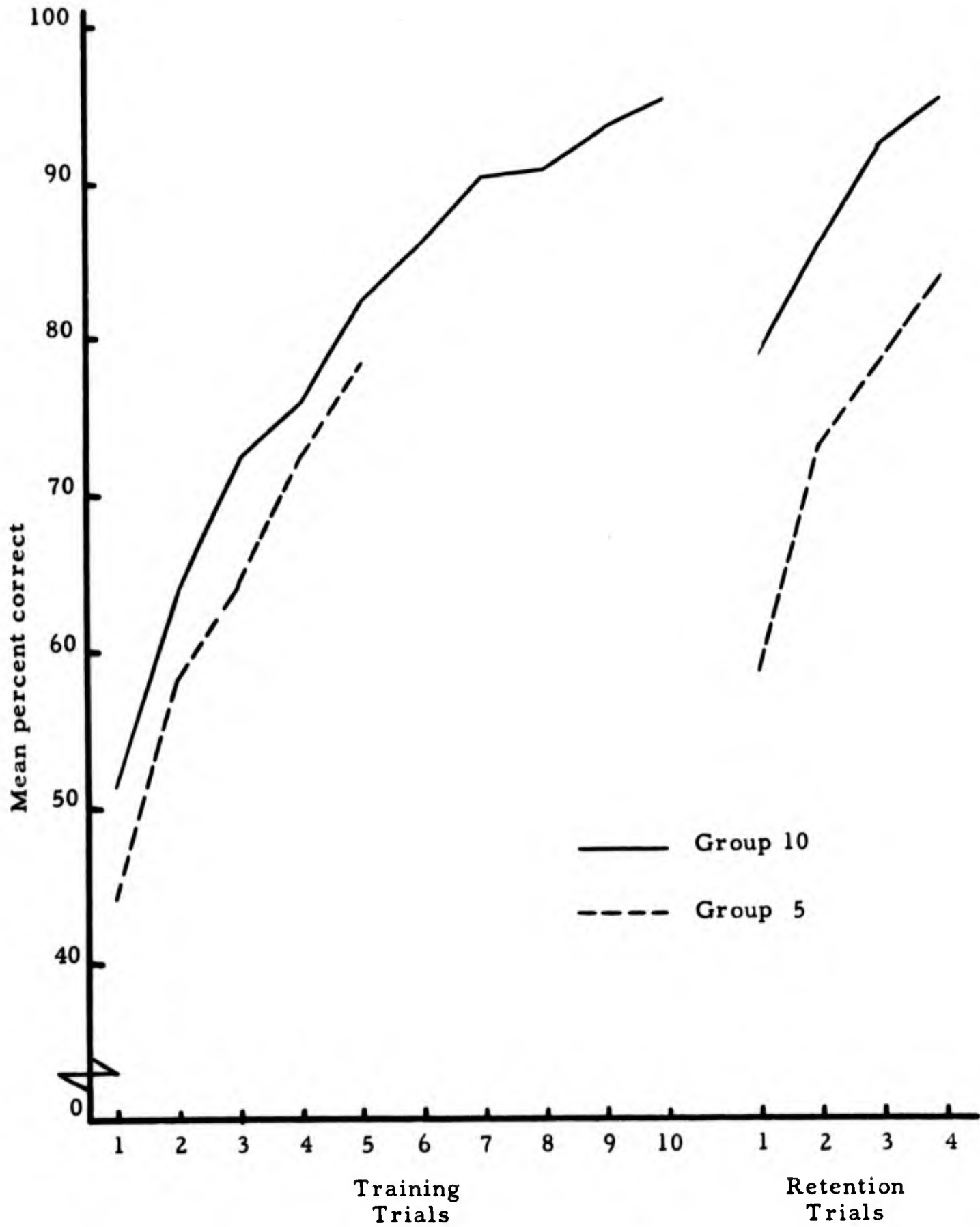


Figure 8. Performance on all procedures.

Training Trial 1 range between 40 and 60 per cent correct and indicate that about half of the procedural responses were learned in academic training and on the familiarization trial. Appendix E presents additional detailed data on procedures, including scores on individual procedural sequences comprising each of the categories.

Retention loss. Table 5 gives the mean per cent loss in proficiency for the four categories of procedures. For both groups, dynamic procedures tend to show the least forgetting. Table 6 gives the results of a t test for the retention loss of each group on each category of procedures. In all instances, the observed difference between the final training trial and the first retention trial has a probability of chance-occurrence of .02 or less, indicating statistically significant losses in performance level over the four months' retention interval. Appendix F gives the results of t tests for the separate procedural sequences of the categories.

To determine for each category whether the retention loss was the same for both groups, a t test of the null hypothesis was made of the difference between the two retention loss values for the groups. A summary table for these tests is presented in Table 7. Group 5 has a significantly larger retention loss for static procedures. Differences for all other categories lack statistical significance.

TABLE 5

Mean per cent retention loss for each category of procedural sequences

Procedures Category	Group	
	10	5
Static	20.9	28.2
Dynamic	11.1	10.2
Emergency	16.7	20.0
All procedures	16.5	20.1

TABLE 6

t test of mean difference in errors between final training trial and first retention trial for each category of procedural sequences

Procedure Category	Group 10			Group 5		
	Mean Diff.	<u>t</u> *	Reliability of Diff.	Mean Diff.	<u>t</u> *	Reliability of Diff.
Static	7.8	2.8	.02 > P > .01	15.9	12.3	< .01
Dynamic	5.2	4.1	< .01	4.9	2.7	.02 > P > .01
Emergency	3.5	3.6	< .01	4.2	3.5	< .01
All procedures	16.5	4.7	< .01	25.1	7.8	< .01

*12 df

TABLE 7

t test of mean difference in retention loss between Group 10 and Group 5 for each category of procedural sequences

Procedure Category	Mean Retention Loss		Mean Diff.	<u>t</u> *	Reliability of Diff.
	Group 10	Group 5			
Static	7.8	15.9	8.1	2.6	.01 < P < .02
Dynamic	5.2	4.9	0.3	0.1	NS
Emergency	3.5	4.2	0.7	0.5	NS
All procedures	16.5	25.1	8.6	1.8	NS

*24 df.

Trials to relearn. Table 8 gives the retention trial number for each category of procedures where the mean performance level on the final training trial is first equalled or exceeded. This value is taken as the number of trials to relearn to the performance level achieved on the final trial before the retention interval. Table 8 shows that at least two trials were required and four or more trials was the most common requirement. Group 10 shows a tendency to require more trials to relearn than Group 5.

TABLE 8

Trials to relearn. For each category of procedures, the tabled value is the number of the retention trial where the mean performance level on the final training trial is first equalled or exceeded

<u>Procedures Category</u>	<u>Group 10</u>	<u>Group 5</u>
Static	>4*	4
Dynamic	>4*	2
Emergencies	4	3
All procedures	>4*	4

*Mean performance level of the final training trial was not yet attained on the final retention trial.

Other measures of proficiency in emergency procedures. In addition to the error--no error discrete items of an emergency sequence, minimum airspeed achieved, altitude lost, and time to complete the sequence were recorded as important aspects of pilot proficiency in correcting the emergency.

For both emergencies, it was desired that an airspeed of 110 MPH be established at the onset of the emergency warning cue and held until the emergency was corrected. In the fuel warning emergency the subject, in establishing a glide, had to pull the nose of the aircraft up to allow the airspeed to drop off to the required 110 MPH. The common error was to forget to lower the nose to enter the glide, with the result airspeed fell below 110 MPH. In the case of the prop overspeed emergency, after

establishing a glide airspeed of 110 MPH, the procedure called for the nose to be raised momentarily while actuating the wobble pump. Failure to perform this aspect of the emergency with skill and precision resulted in airspeed dropping below 110 MPH.

Both emergencies called for reducing airspeed and establishing a glide, which resulted in some loss of altitude. As the subject became more proficient the emergency was corrected in less time and the glide maneuver was performed with greater precision. Consequently less altitude was lost on successive training trials.

As the experiment progressed it became evident that the measure of time to complete an emergency sequence was not singularly meaningful because a subject could have a fast time score by either performing the sequence rapidly and omitting several items or performing the sequence rapidly with no omissions. Another consideration is that when a subject forgets procedural items over the retention interval his performance involves fewer items and could take less time than in the training trials. For these reasons the time measure is not an unequivocal index and should be interpreted with caution.

Figures 9 - 11 show the performances on altitude lost, minimum airspeed achieved, and time to complete the sequence for the two emergencies combined. All show a progressive learning effect over the training trials. Mean altitude lost for Group 10 stabilizes at 400 - 500 feet. In the opinion of the experimenters, proper corrective action should entail this much altitude loss.

Table 9 reports mean per cent loss for these three measures. Group 10 has some retention loss for all measures, whereas Group 5 has a gain over the retention interval for minimum airspeed and time to complete the sequence, with only altitude lost showing a decrement over interpolated time. Table 10 gives the results of a t test for the retention loss of each group for each of the three measures. All tests lack statistical significance with the exception of altitude lost for Group 5.

To establish for each measure whether the retention loss was the same for both groups, a t test of the null hypothesis was made of the difference between the retention loss values of the two groups on each maneuver. These tests are shown in Table 11. None are significant. For each measure the retention losses of the two groups can be considered the same.

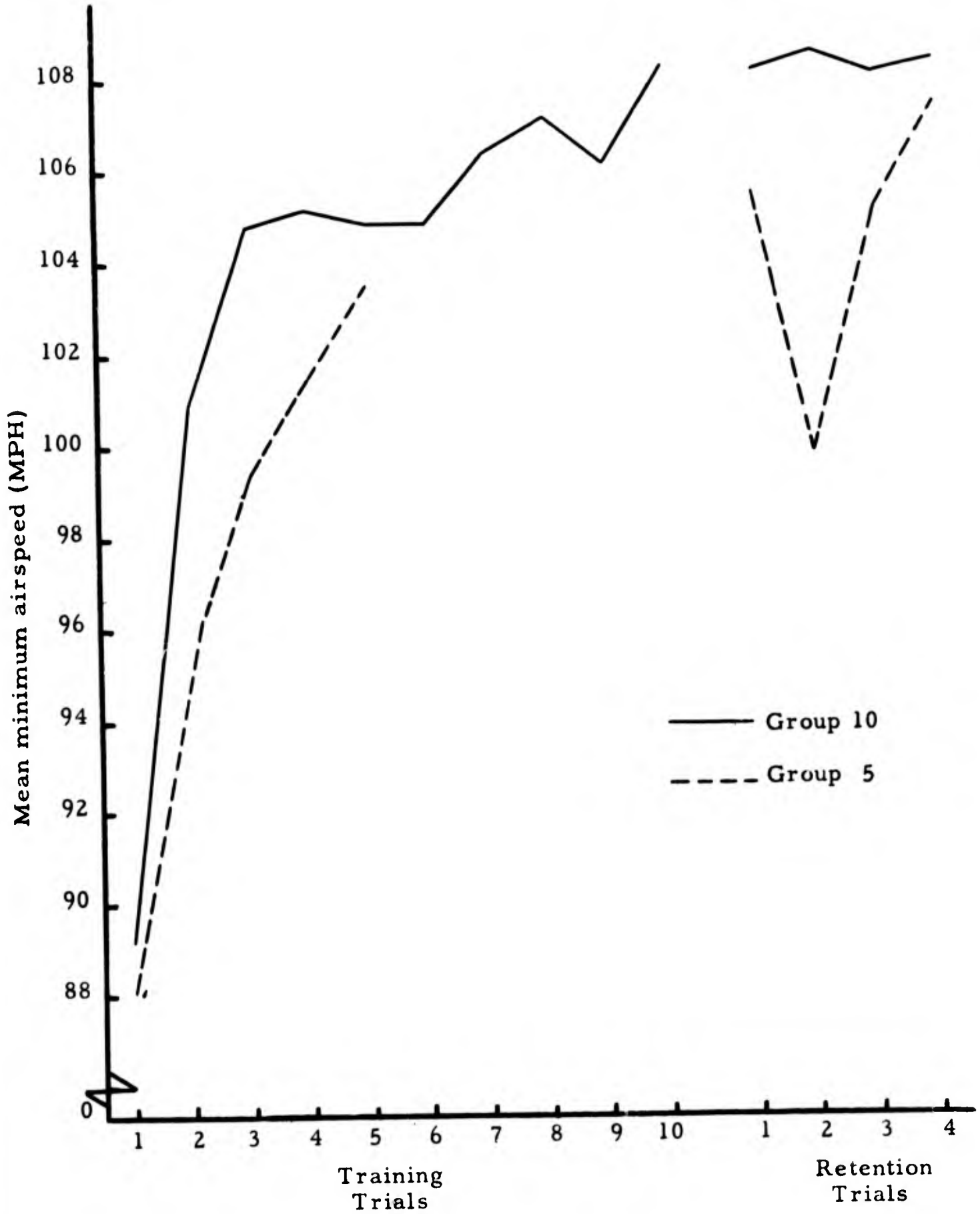


Figure 9. Minimum airspeed achieved during emergency procedures. Desired value is 110 MPH. Airspeed values are averaged over both emergency sequences.

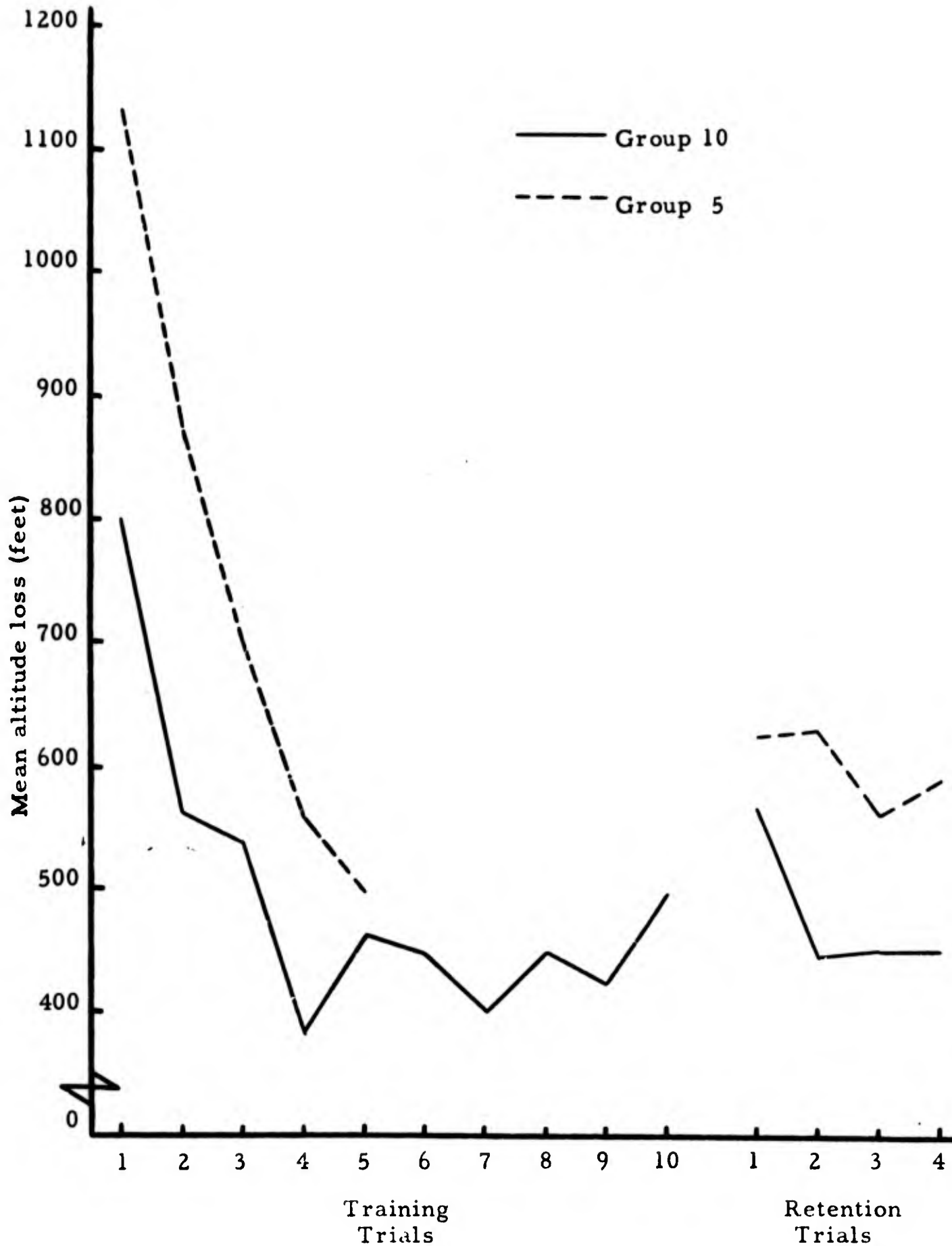


Figure 10. Altitude loss on emergency procedures. Altitude values are averaged over both emergency sequences.

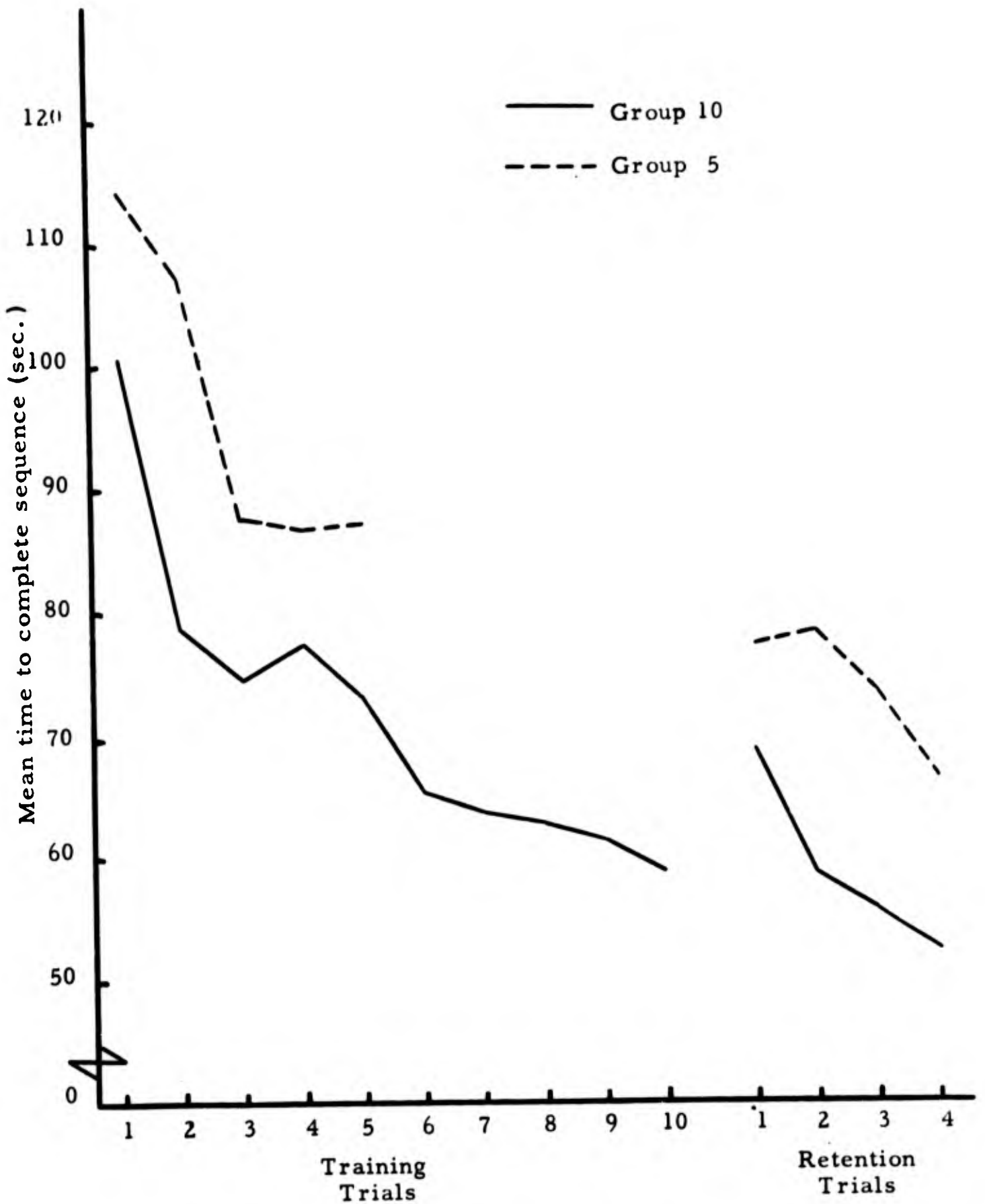


Figure 11. Time to complete sequence of emergency procedures. The time values are averaged over both emergency sequences.

TABLE 9

Mean per cent retention loss for minimum airspeed achieved, altitude lost, and time to complete sequence for the two emergency procedural sequences combined

<u>Measure</u>	<u>Group 10</u>	<u>Group 5</u>
Minimum airspeed	1.1	-14.2*
Altitude lost	11.0	20.5
Time to complete sequence	23.5	-37.9*

*Minus sign signifies a gain over the retention interval.

TABLE 10

t test of mean difference between final training trial and first retention trial for minimum airspeed achieved, altitude lost, and time to complete sequence for the two emergency procedural sequences combined.

<u>Measure</u>	Mean <u>Group 10</u> Diff.	<u>t</u> * Reliability of Diff.	Mean <u>Group 5</u> Diff.	<u>t</u> * Reliability of Diff.
Minimum airspeed (MPH)	0	2.1 NS	-3.9	1.2 NS
Altitude lost (feet)	69.2	0.7 NS	130.4	5.4 <.01
Time to complete sequence (sec.)	10.0	2.1 NS	-10.2	1.1 NS

* 12 df.

TABLE 11

t test of mean difference in retention loss between Group 10 and Group 5 for minimum airspeed achieved, altitude lost, and time to complete sequence for the two emergency procedural sequences combined

Measure	Mean Retention Loss		Mean Diff	<u>t*</u>	Reliability of Diff.
	Group 10	Group 5			
Minimum airspeed (MPH)	0.1	-3.9	4.0	1.0	NS
Altitude lost (feet)	69.2	130.4	61.2	0.3	NS
Time to complete sequence (sec.)	10.0	-10.2	20.2	1.4	NS

* 24 df.

Table 12 presents the data on trials to relearn. Appendix G presents the values for these three measures on each trial.

TABLE 12

Trials to relearn. For minimum airspeed achieved, altitude lost, and time to complete sequence for the two emergency procedural sequences combined, the tabled value is the number of the retention trial where the mean performance level on the final training trial is first equalled or exceeded

<u>Measure</u>	<u>Group 10</u>	<u>Group 5</u>
Minimum airspeed	2	0**
Altitude lost	2	> 4*
Time to complete sequence	2	0**

*Mean performance level on final training trial was not yet attained on the final retention trial.

**Zero relearning trials signifies a gain in performance level over the retention interval

Retention of Flight Parameters

Learning to control flight parameters. Figures 12 - 16 present the performance curves of the two groups for the five flight parameters recorded as indices of the ability to control the simulated aircraft. As with measures of proficiency in procedures, all measures of flight parameters show the traditional negatively accelerated learning functions over training trials. Appendices H and I present detailed data for these five measures. Appendix I also has the values for directional bank errors, i. e., the brief movements of the aileron control in the wrong direction at the initiation or completion of a turn. No analyses of directional bank errors were made because the number was considered too small.

Retention loss. Table 13 shows the mean per cent retention loss for the five measures. Group 10 has per cent losses of about the same approximate magnitudes as it had for the four categories of procedures. The per cent loss values for Group 5 indicate a loss standing in much higher proportion to the amount learned in the training trials, however this can be considered an artifact of the computational formula for per cent retention loss, as discussed earlier. Table 14 gives the results of a t test for the retention loss of each group on each flight parameter. Statistical significance for flight parameters was obtained less frequently than for procedures. Whereas the retention losses for both groups on all four categories of procedures were significant, only two of the five flight parameters had statistically significant losses for both groups. Error in bank was significant only for Group 5. The other two measures were not significant for either group. Statistical tests of the retention loss on each individual maneuver are shown in Appendix J.

TABLE 13

<u>Mean per cent retention loss for each flight parameter</u>		
<u>Flight Parameter</u>	<u>Group 10</u>	<u>Group 5</u>
Altitude	18.4	25.0
Bank	23.1	50.0
Airspeed	17.8	96.0
Level-off at altitude	3.1	32.3
Roll-out on new heading	15.2	62.5

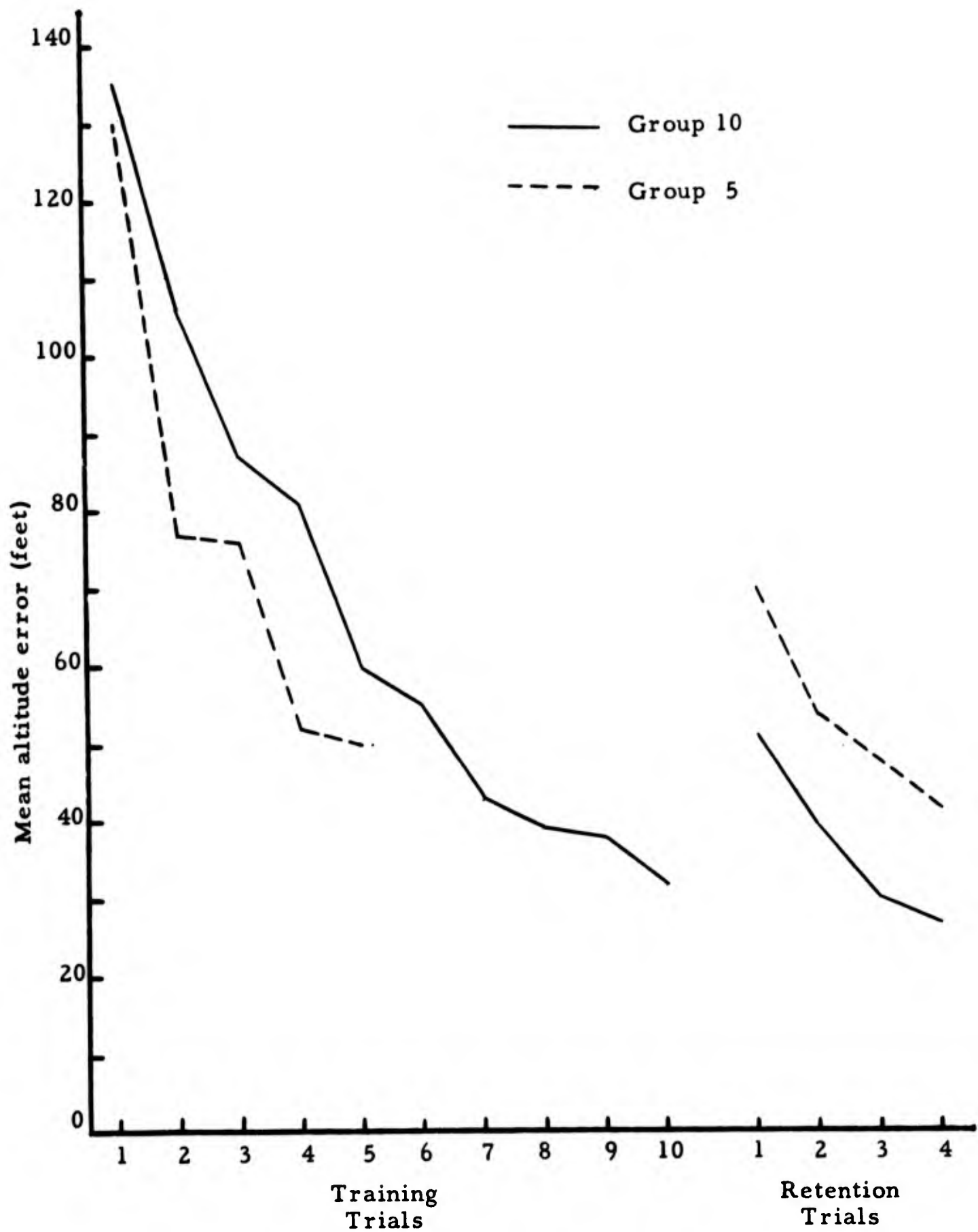


Figure 12. Accuracy in controlling of altitude. Averaged over all maneuvers

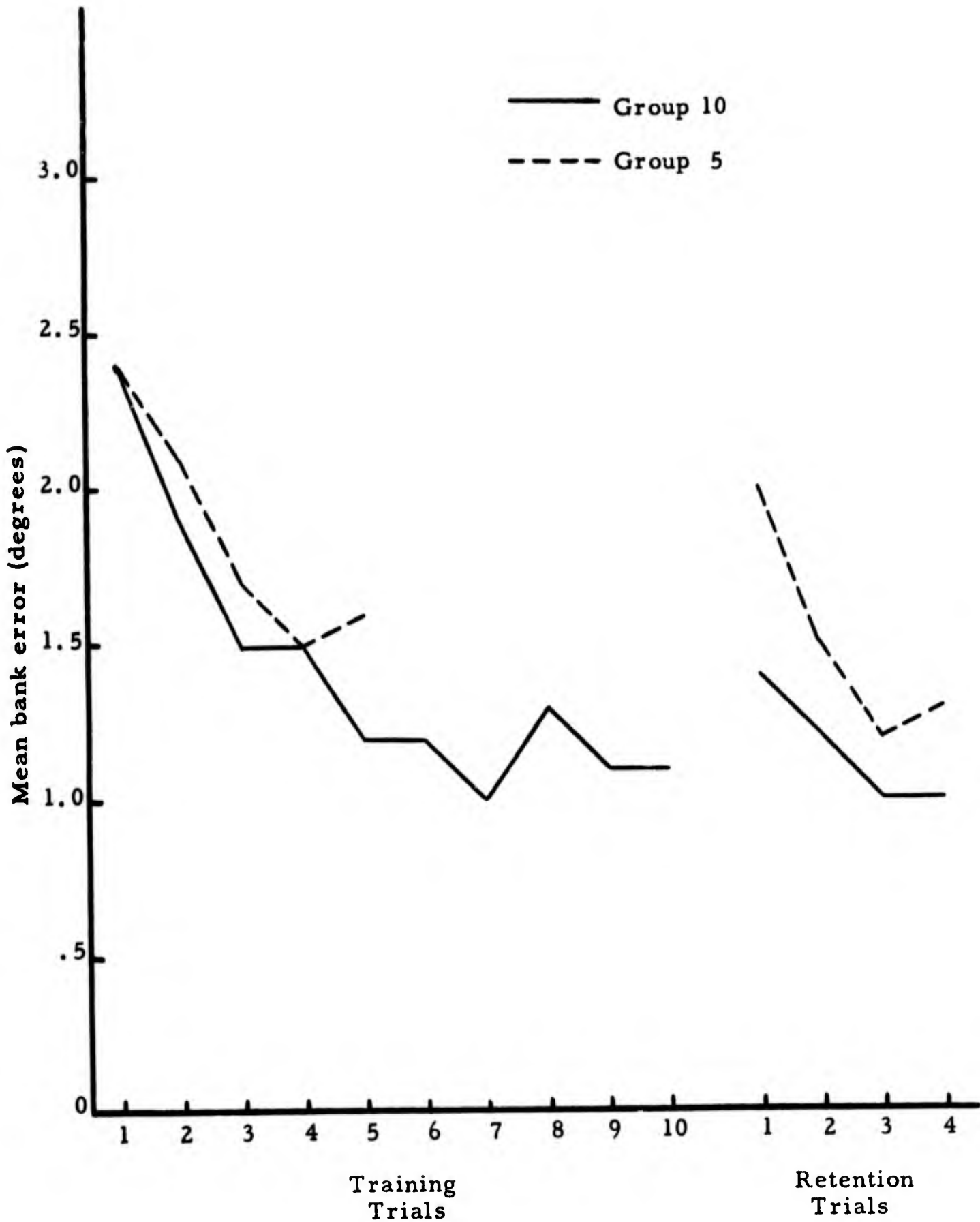


Figure 13. Accuracy in controlling of bank attitude. Averaged over all maneuvers.

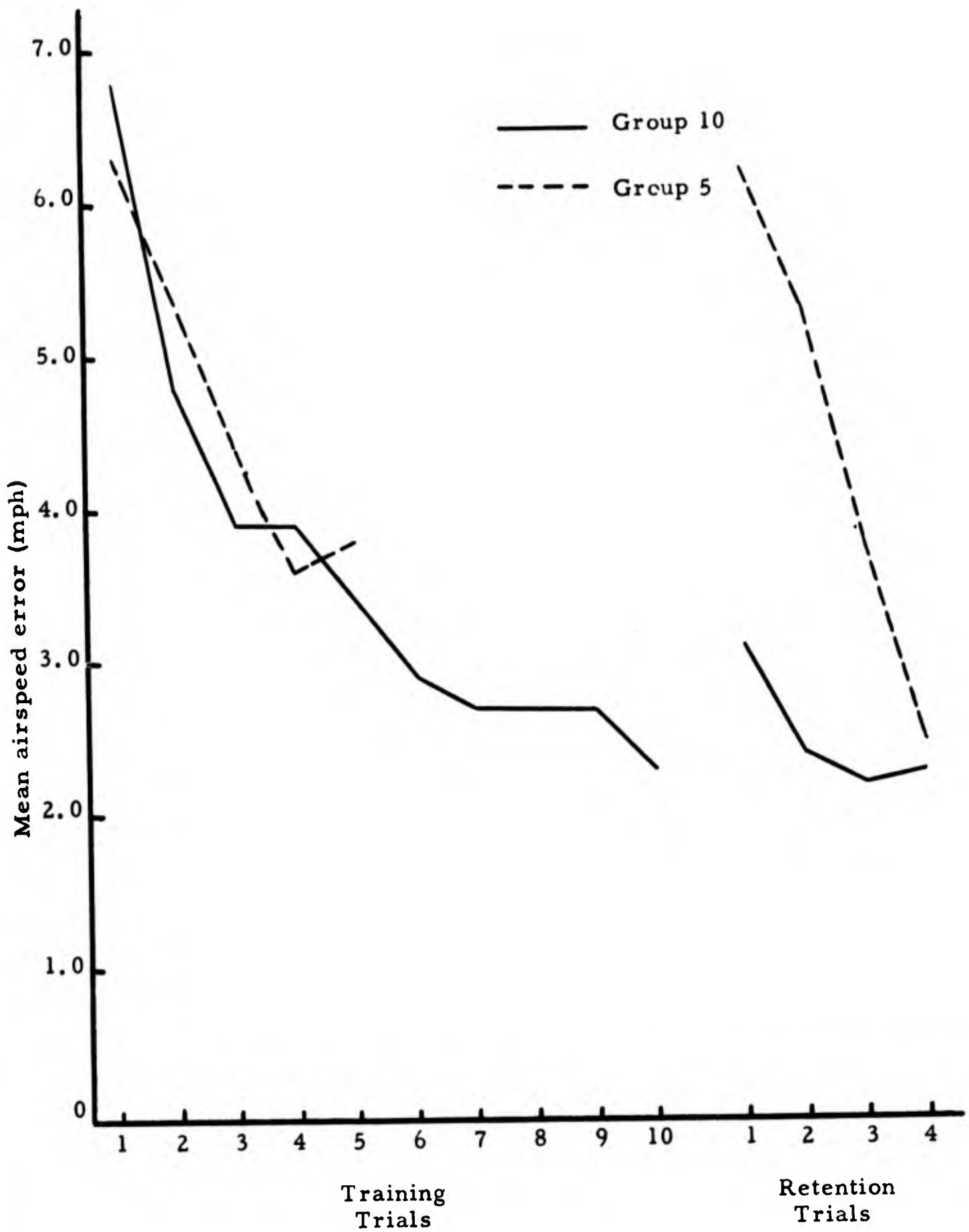


Figure 14. Accuracy in controlling of airspeed. Averaged over all maneuvers.

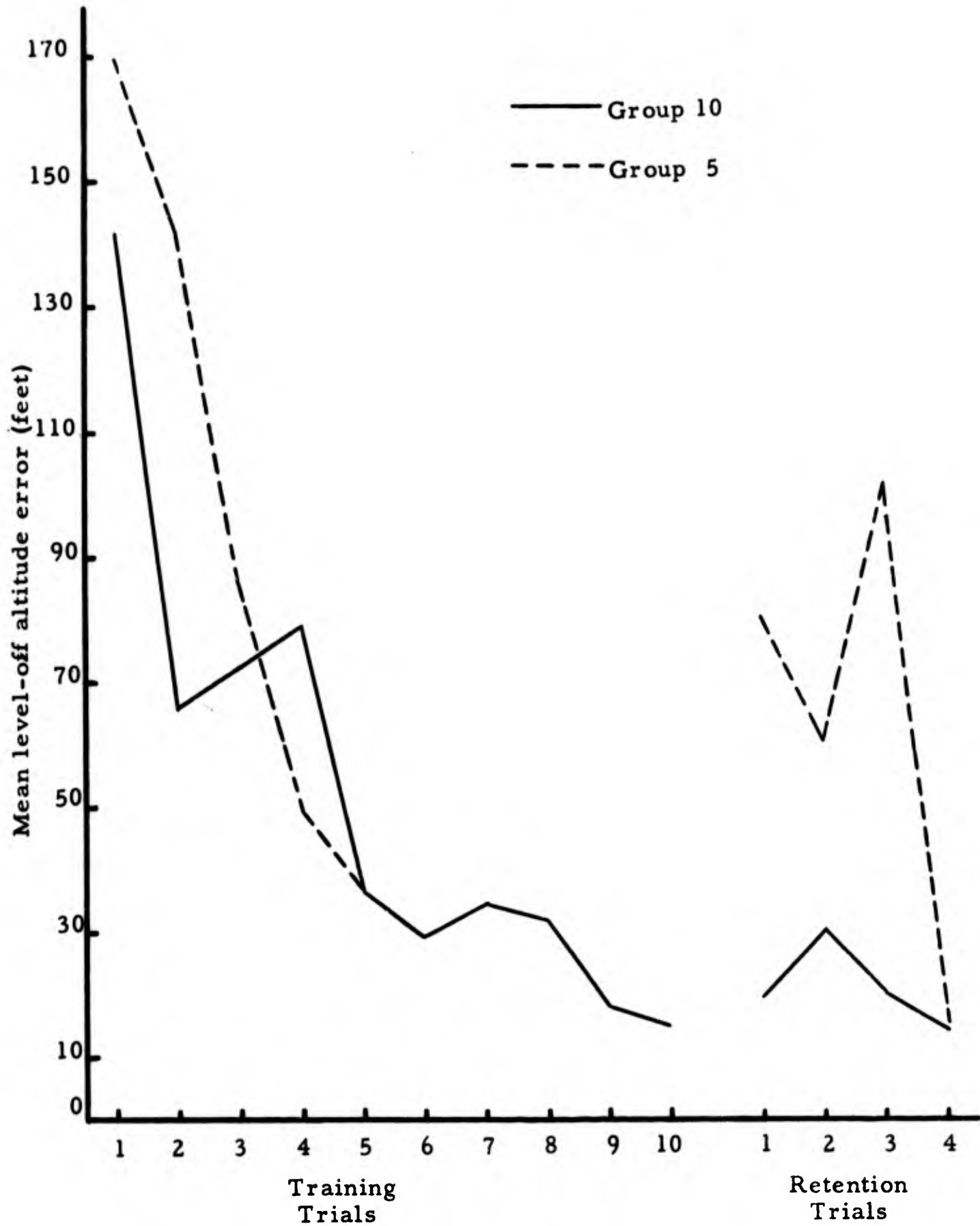


Figure 15. Accuracy of leveling off at the correct altitude. Averaged over all maneuvers.

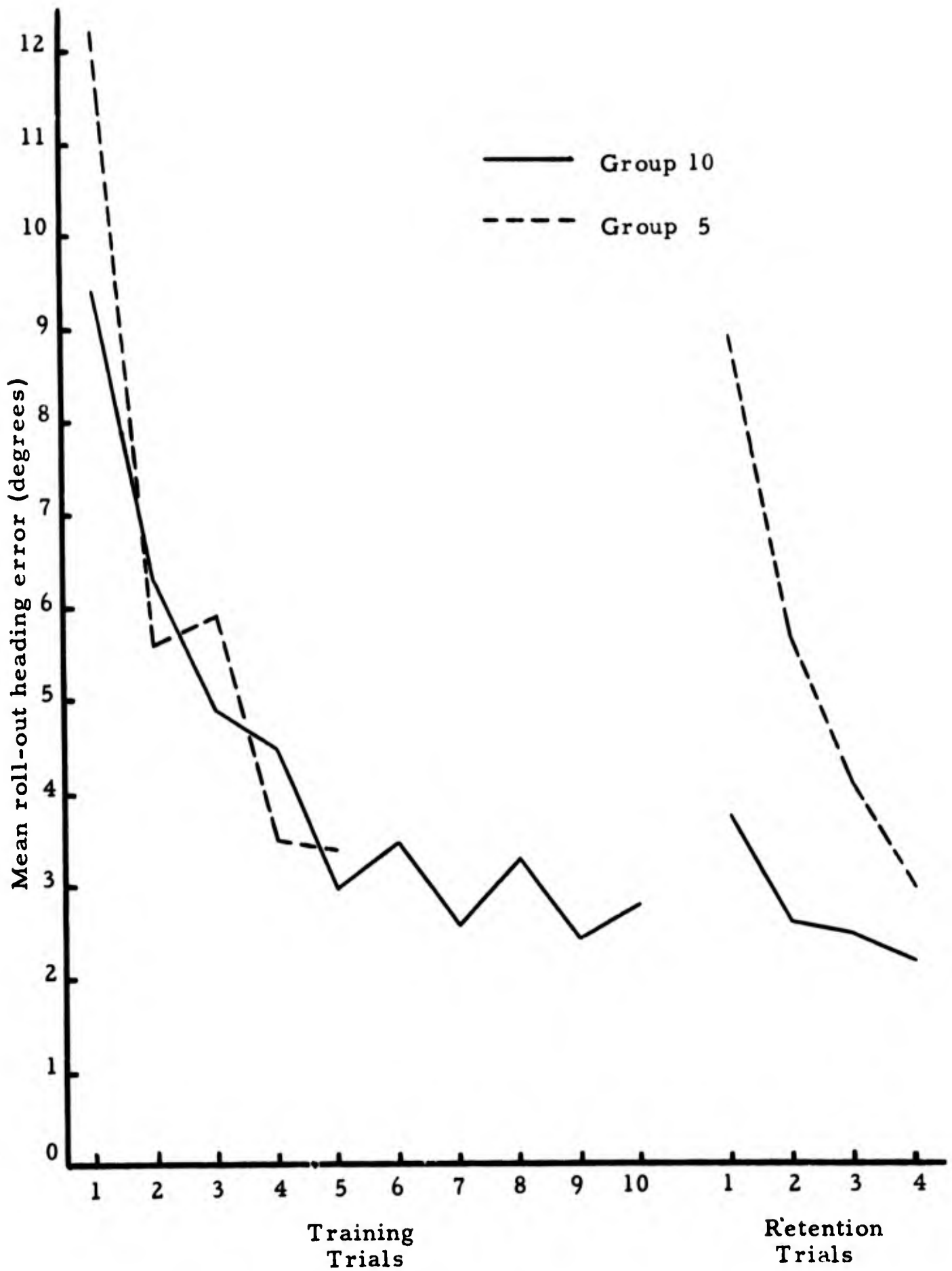


Figure 16. Accuracy in achieving correct heading at the termination of a turn. Averaged over all maneuvers.

TABLE 14

t test of mean difference between final training trial and first retention trial for each flight parameter

Flight Parameter	Group 10			Group 5		
	Mean Diff.	t*	Reliability of Diff.	Mean Diff.	t*	Reliability of Diff.
Altitude (feet)	19.7	2.4	.05 > P > .02	19.3	4.1	< .01
Bank (degrees)	0.3	1.6	NS	0.4	3.0	.02 > P > .01
Airspeed (MPH)	0.9	2.7	.02 > P > .01	2.3	2.4	.05 > P > .01
Level-off at altitude (feet)	6.2	1.8	NS	44.1	2.0	NS
Roll-out on new heading (degrees)	1.0	1.4	NS	5.5	1.9	NS

* 12 df.

To determine for each flight parameter whether the retention loss was the same for both groups, a t test was performed on the difference between the retention loss values of the two groups. The results of these tests are given in Table 15. None are statistically significant.

TABLE 15

t test of mean difference in retention loss between Group 10 and Group 5 for each flight parameter

Parameter	Mean Retention Loss		Mean Diff.	t*	Reliability of Diff.
	Group 10	Group 5			
Altitude (feet)	19.7	19.3	0.4	0.1	NS
Bank (degrees)	0.3	0.4	0.1	0.4	NS
Airspeed (MPH)	0.9	2.3	1.4	1.4	NS
Level-off at altitude (feet)	6.2	44.1	37.9	1.7	NS
Roll-out on new heading (degrees)	1.0	5.5	4.5	1.5	NS

*24 df.

Trials to relearn. The retention trials taken to relearn to the performance level attained on the final training trial is given in Table 16. In all cases, at least two trials were needed, but in no instance was more than four required.

TABLE 16

Trials to relearn. For each flight parameter, the tabled value is the number of the retention trial where the mean performance level on the final training trial is first equalled or exceeded.

<u>Flight Parameter</u>	<u>Group 10</u>	<u>Group 5</u>
Altitude	3	3
Bank	3	2
Airspeed	3	3
Level-off at altitude	4	4
Roll-out on new heading	2	4

DISCUSSIONS AND RESULTS

The salient findings of this study are:

1. Discrete procedural responses are more susceptible to forgetting than continuous tracking responses. For both groups, all four categories of procedural responses had a statistically significant retention loss over the retention interval. Of the five flight parameters, only two had a significant loss over the retention interval for both groups. The retention loss for the bank parameter was significant for Group 5 only, and the other two parameters did not have a significant loss for either group.

2. Dynamic procedures (those requiring concurrent flight control) revealed a statistically significant retention loss for each group but the loss tends to be less than for other categories of procedures. Measures of aspects of flight control during an emergency (minimum airspeed achieved,

altitude lost) did not, in general, show a retention loss. There is no apparent explanation of why behavior suddenly elicited without warning should show less forgetting.

3. With one exception, the amount of initial training did not influence the amount of the retention loss. A corollary of this finding is that the more highly trained Group 10 was always superior to Group 5 on the first retention trial, showing that a high level of initial training pays off in a higher performance level after a retention interval.

4. The number of trials taken to relearn is a positive function of the amount of initial training, and is less than that taken to train originally. Some of the measures took more than the four retention trials to attain the performance level held on the final training trial. If an arbitrary value of five is assigned as the number of trials taken to relearn for those measures not relearned by the fourth retention trial, and the mean number of trials to relearn is then computed for the twelve major measures of flying proficiency treated (seven of procedures, five of flight parameters), Group 10 required an average 3.3 trials and Group 5 an average of 2.8 trials to relearn.

The findings of this study are consistent with those of Ammons et al. (1) in demonstrating that selective procedural responses are more labile and susceptible to forgetting influences than tracking responses, that the number of trials to relearn are a positive function of the amount of original training, and that fewer trials are required to relearn than were needed in original learning. Inconsistent with the study by Ammons et al. is that the amount of retention loss is not differentially affected by the amount of original training. An interesting quantitative difference between the present study and that of Ammons et al. concerns the amount of time taken to relearn. For their study, using simple procedural and tracking tasks, the amount of time to relearn was a matter of a few minutes. In our study, utilizing the relatively complex SNJ OFT, Group 5 required a mean of 2.8 trials to relearn and Group 10 required 3.3 mean trials. With each trial being about 50 minutes in duration (depending upon the proficiency of the subject), something in the vicinity of three hours

of retraining was needed to regain the lost skill. Why the time to retrain is a function of task complexity is a speculative matter. In the case of procedures, complexity might be measured simply in terms of the number of responses and time to relearn may be a direct function of this variable. Ammons et al. had 15 procedural items and we had 125. For tracking, the dimensions of complexity are many and any one or combination of them might contribute to differences in time to relearn. Ammons et al. used a simple compensatory tracking task, the Plane Control Test, where a model airplane is unsystematically displaced in pitch, bank, and yaw and the subject is required to null the error by appropriate counter-actions of the stick and rudder. The Plane Control Test is a position tracking task having a simple linear relationship between the movement of the airplane in each dimension and the movement of the related control. In contrast, an OFT has control-display relations that are much more complex than the simple position tracking of the Plane Control Test and the learning of more intricate movement patterns is demanded. Furthermore, an OFT is a multidimensional tracking task which requires a component tracking response to each stimulus source on the panel display, as well as a visual scanning component response to detect deviations to be corrected in each source. The overall forgetting in an OFT could be a function of the forgetting of one or more aspects of its many component responses, and the time to relearn could be attributed to overcoming the loss in each component response and in re-establishing the smooth coordinated integration among them. For example, let us suppose that the component responses of visual scanning and acceleration tracking for bank are both partly forgotten. Because of the inadequate visual response on the first retention trial, the subject is not sensing the attitude indicator displaying bank error with sufficient frequency to permit adequate practice of the component tracking response for bank. Only when the visual scanning response has been sufficiently relearned is the subject able to give sufficient attention to bank error and systematically practice the component tracking response needed to correct it. When we consider that a complex task like an OFT probably has a number of component responses that interact in this fashion, it is not unreasonable to expect a considerable relearning time to overcome all of the forgetting effects and re-establish the level of proficiency

held just prior to the retention interval. A basic program of research on forgetting as a function of the characteristics of complex tasks is urgently needed. A complete understanding of the forgetting of behavior in complex tasks requires systematic basic investigations on how forgetting of total behavior in a complex task is related to the forgetting of constituent component responses.

The previous statement that procedural responses are more susceptible to forgetting than tracking responses needs qualification. This difference in forgetting characteristics could be the inherent nature of the two response classes but an alternative explanation concerns equating the amount of practice. Within the context of this experiment, or any other retention experiment for that matter, there is no way of operationally defining the statement that two different classes of responses each measured differently have equal levels of learning. Thus we usually should expect unequal levels of learning for the two response classes and these different levels of learning might in some cases mean unequal amounts of forgetting. Therefore, we are not fully justified in implying the generalization that procedural responses are more readily forgotten than tracking responses. This generalization may indeed be correct but it cannot be made securely until the measures for the two different response classes can be placed on a common scale of measurement. At present there is no known solution to this methodological problem in retention research. Our findings have importance within the practical context of aviation but the fundamental significance of the findings must at this time be qualified.

Operational implications. The most important implication for operational flight training is that procedural responses show retention losses that are not only statistically but practically (operationally) significant whereas measures of proficiency for flight parameters are operationally insignificant throughout, even in the instances when they are statistically significant. For example, Group 10 had a mean loss of only 19.7 feet of altitude, and Group 5 had a loss of 19.3 feet of altitude, both statistically significant. Significant mean loss in airspeed amounted to 0.9 MPH for Group 10 and 2.4 MPH for Group 5. Clearly the absolute amounts of these losses cannot be construed as operationally important.

However, the loss of 16.5 per cent of all procedures by Group 10 and 20.1 per cent by Group 5 unquestionably means a serious degradation in flying proficiency, particularly when emergencies are involved. The implications of this are even stronger when we remember that modern manned air weapons systems are turning increasingly to automatic flight control for many operations, with procedural and decision-making activities being the major contributions of the pilot.

The findings of this study strongly suggest that programs directed toward the maintenance of flying proficiency should focus on the training of procedures. From the standpoint of economy this is perhaps fortunate because procedures are undoubtedly the easiest to train and, in most instances, can be taught by ground methods and devices. It is noteworthy that about half of the 125 procedural items of this study were learned prior to the first training trial, indicating that four hours of academic training and one familiarization trial were potent training techniques. Since many procedures might be broadly conceived as intellectual in nature, a great deal of training can be accomplished with conventional classroom training aids. Research has shown that a simple, full-scale photographic mock-up of the cockpit can be effective (2). For other types of procedures where the stimuli occur as changes in the instrument panel and where the pilot must learn the location of various control items, a low-cost cockpit procedures trainer having the cockpit layout of the aircraft that is regularly flown would be very useful. However, it should be kept in mind that certain procedures are a matter of timing instrument flying sequences (when and what to do next) and these would seem to require a general instrument flight trainer (general configuration of a class of aircraft) or an OFT (configuration of a specific aircraft). An OFT is the best all-round training device because all classes of procedures can be practiced in it, as well as general instrument flying skills. However, OFT's are complex electronic devices that have high initial and maintaining costs. In lieu of OFT's, a judicious combination of classroom training, a general instrument flight trainer, and a cockpit procedures trainer, should be considered.

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TECHNICAL APPENDIX

- A Academic Training
- B Flight Task Instructions
- C Data Sheets for Performance Recording
- D Scoring Rules
- E Detailed Data on Procedural Sequences
- F \underline{t} Tests for Related Measures of the Mean Difference In Errors Between Final Training Trial and First Retention Trial for Separate Procedural Sequences
- G Values on Each Trial for Performance on Flight Parameters During Emergencies and for Time to Complete Emergency Procedural Sequences
- H Values for the Flight Parameters of Altitude, Airspeed, and Bank for Each Trial for Each Maneuver
- I Values on Individual Trials for Error on the Initiation or Completion of a Maneuver
- J For Each Group, \underline{t} Test for Related Measures of the Mean Difference Between Final Training Trial and First Retention Trial for the Absolute Error in Altitude, Bank, and Airspeed on the Individual Maneuvers of the Flight

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ACADEMIC TRAINING

PERIOD ONE

Much of the information presented in this period was read verbatim from prepared discussions. These discussions are presented, together with a description of the movies shown. Questions by the subjects were encouraged.

Introductory Statement (verbatim)

"Tonight marks the beginning of a research study involving the retention of flying skills. You have been selected as the (number) participating group and your initial training will be completed before (date). Toward the end of the Spring Semester we will ask you to return for several final trainer flights.

"Normally student pilots are taught to fly contact first, that is, they are able to see the ground and the sky. After learning to fly contact, instrument flight training is introduced in which the visual contact with the ground is removed and complete reliance is placed upon a group of flight instruments on the panel before the pilot. It becomes necessary to interpret the readings on several instruments into an integrated pattern so that safe, coordinated flight is maintained.

"You will receive your training in a Link Flight Trainer that is modeled after the Navy SNJ aircraft. You will be trained to fly solely by instruments, 'under-the-hood' as we say. This will not be an easy task and is not something you learn all at once, but rather with practice. Your training course will consist of two evening ground school sessions, a familiarization hop, and a number of practice hops in the trainer. We firmly ask that you not do any outside study or practice. This is quite important as we desire to control as much as possible the training which you will receive. It is also very important that you do not do any actual flying during this training period. If you contemplate taking flying lessons during this time, we ask that you either postpone your plans or

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cancel your participation in the project.

"Since time is our most important asset, we have built a schedule of proposed hops that best utilizes your free time and the availability of the trainer. We will give you a copy of your schedule so that you will know when to come out. We ask that you extend every effort to meet your scheduled hops. If you find that you cannot make a scheduled hop, we request that you call and let us know."

Movie on the Use of Flight Controls

The movie selected to demonstrate the use of flight controls was the United States Navy training film, No. MN 3474D, "Primary Flight Training -- First Flight, Part I." This film was selected as part of the academic training because of its excellent treatment of flight controls. The method was superimposing an animated wing on actual air-to-ground film sequences. The animated wing is tilted up or down to show a climb or dive, and banked to the right or left to show turning. The control surfaces are then added and their function is demonstrated. At this point, the scene shifts to the actual airplane and further demonstration is made of the effects of control stick movement. Careful explanation is made of the fact that all of the controls operate in relation to the pilot, regardless of the attitude of the aircraft.

Instrument Identification

To acquaint the subjects with the instruments which they would be using, the following prepared discussions were read and correspondingly demonstrated using the instrument mock-up shown in Figure 17, which allows for the manual setting of instrument values.

Attitude Indicator (verbatim). "In visual flight the pitch attitude is attained by raising or lowering the nose in relation to the actual horizon. In instrument flying the attitude indicator supplants the real horizon and exactly the same procedures are followed by raising or lowering the nose of the miniature aircraft on the artificial horizon. Bank attitude is attained in visual flight by raising one wing and lowering the other in relation to the horizon. Again in instrument flight, this same relationship is presented by the miniature airplane and the horizon bar.

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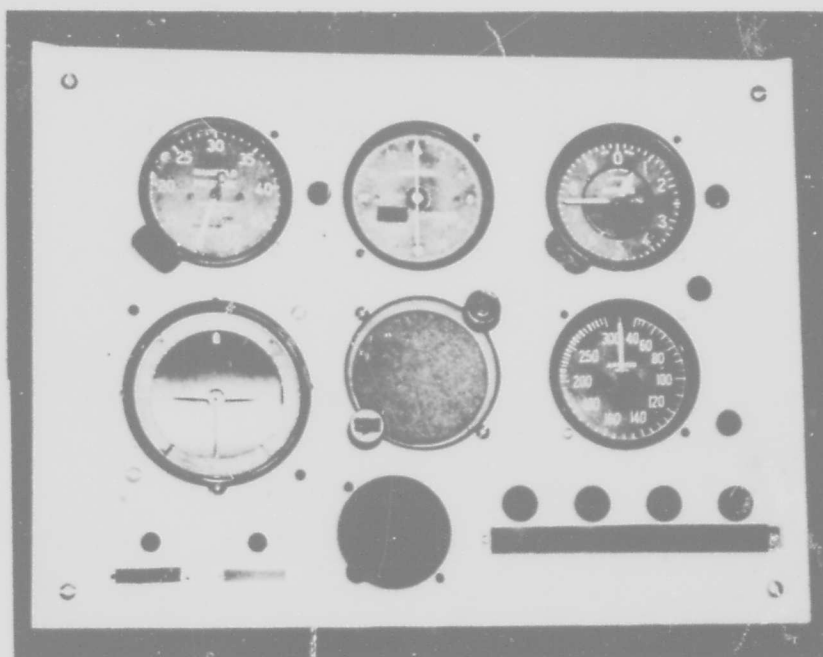


Figure 17. Instrument panel array used in academic training. A knob on the back of each instrument permitted the experimenter to manually set in instrument readings for various flight conditions.

The attitude indicator gives a direct reading of the pitch and bank attitude of the aircraft. By utilizing this instrument the pilot can adjust the nose or wings of the aircraft in any desired position and check the other instruments for the accuracy of this position. There is no lag in this instrument and it gives immediate indications of trends of movement of the aircraft in relation to the actual horizon.

Heading Indicator (verbatim). "The heading indicator is very similar to a compass and has the same type of readings. Most compasses that are used give the direction in terms such as north, east, south, and west. However the heading indicator uses numbers to designate these directions. North on the heading indicator is zero or 360 degrees, East is 90 degrees, South is 180 degrees, and West is 270 degrees. All the headings throughout the 360 degree range are read in number of degrees. An example of this is: Southeast would

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read 135 degrees. The dial of the instrument is graduated in two degree intervals. A long line is placed every ten degrees. Each 30 degrees from zero is marked by a number in this fashion: 0, 3, 6, 9, 12, and so on. Notice that each number has the zero removed. We must add this when reading the instrument. The instrument is read in a clockwise direction. If the needle is on the second degree line past first ten degree line, past the number 15, the heading is read 164 degrees. Remember in reading the instrument, there is a zero added to each of the numbers that appear on the dial face.

"The heading indicator gives an immediate indication of turning through needle movement in the direction of the turn. This instrument only gives the indication that there is a turn being performed and does not give information as to the angle of the bank. Therefore, this instrument is only a supporting instrument for the attitude indicator. Any changes in the bank attitude can be discovered through the combined use of the attitude and heading indicators.

"When turning right the pointer moves in a clockwise direction and there is an increase of heading. When turning left, the converse is true. When the pointer moves counter-clockwise there is a decrease in the heading.

Altimeter (verbatim). "The altimeter is the instrument that gives the height of the aircraft above the ground. It is calibrated in feet with 20-foot increments as the smallest interval and 100 feet for the other interval. Each 100-foot interval is numbered with the last two zeros removed, such that the number 8 would read 800 feet. The long needle on this instrument gives the altitude in feet or hundreds of feet. When the long needle makes one complete circuit, the altitude is 1000 feet. (Demonstrate) You will notice that the shorter needle is reading 'one' which is where we get our indications of 1000's of feet. Each circuit of the long needle will move the shorter one up one more number. When you climb, the long needle will continually increase its reading and in doing so the shorter needle will also increase its readings. Remember the large needle marks off hundreds of feet while the short needle marks off the 1000's of feet. You might compare this to the minute and hour hands of a clock.

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Airspeed Indicator (verbatim). "The airspeed indicator tells the pilot how fast he is traveling through the air. We might compare this instrument to a car's speedometer in that they both indicate speed in relation to something else. The airspeed indicator is read directly. No zeros have to be added. If the needle is pointing to 140, this would read as 140 MPH.

Manifold Pressure Gauge (verbatim). "This instrument gives an indication of the amount of power you are receiving from the engine. It is graduated in inches of mercury. The needle moves in a clockwise direction and gives a direct reading of the pressure that the fuel-air mixture is being forced into the engine at a point in the intake manifold. This gauge will be utilized for power changes at various points in the flight. The throttle controls the manifold pressure. To increase the pressure move the throttle forward and to decrease the pressure move the throttle aft. Every mark on this instrument represents one inch of manifold pressure. There is some lag in this instrument when the throttle is moved, and this necessitates a gross movement of the throttle at first, followed by a final adjustment a few seconds later."

Movie on Attitude Instrument Flight

The task of finding a movie which would demonstrate attitude instrument flying to the basic degree which would be required for participation in this experiment proved to be rather difficult. The films that were reviewed were found to contain many points and demonstrations which were not applicable or necessary. In order to get maximum use of time devoted to movies, it was decided to make a composite of two films. It was deemed necessary to give the subjects some idea of just what was going on outside of the airplane when engaged in instrument flying, keeping in mind that these subjects have had little or no experience in an airplane. It was felt that they would have a better concept of what was going on if the takeoff and flight through instruments could be demonstrated on film. With that in mind, parts of the following two films were utilized to bring out the points believed to be most important for the training of the subjects.

The first part of the composite film was taken from the United

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States Navy training film, No. MN 7398B, "Flight Training -- Takeoffs, Approaches, and Landings." This film was selected because it utilizes the SNJ aircraft and demonstrates the takeoff under contact conditions. The shots in the film display the interior of the cockpit showing the pilot's hands and feet. It demonstrates the takeoff from the pilot's view inside the cockpit, and it was hoped that this would give the subjects some visualization of what they would be doing under the hood.

The second part was taken from the United States Navy training film, No. MN 6773A, "Flight Through Instruments -- Basic Instrument Flying." Parts of this movie were selected for the purpose of showing the transition from contact to instrument flight, demonstrating that a pilot must visualize through the instruments what the plane is doing. Attitude flight is defined as flight that is controlled entirely by the pilot through the use of instruments. Pitch and bank attitude are defined and demonstrated. The axiom, attitude plus power determines flight performance, is presented by demonstrating what happens when power is added and reduced when under normal trim conditions, and how to use the trim tabs to correct for these power changes. The film describes the attitude indicator, altimeter, and airspeed indicator and shows how they are used in attitude flight. The use of a power differential for making airspeed changes is also demonstrated.

Attitude Instrument Flying Discussion (verbatim)

"Attitude instrument flying, as seen by the film is the relationship of the longitudinal axis (fuselage), its lateral axis (wings) to the earth's surface or any plane parallel to the earth's surface. Attitude instrument flying is controlling the attitude of the aircraft by reference to the flight instruments.

"Attitude flying is similar to visual flying in that both methods use reference points to determine the attitude of the aircraft. In visual flight the attitude of the aircraft is determined by reference to the real horizon while in instrument flying the reference is to the flight instruments, which give essentially the same information that is obtained by visual reference to the real or visual horizon. Another similarity is in the manner in which the aircraft is controlled. The pilot uses the exact

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same techniques in instrument flying as is used in visual flight. The most difficult factor for you will be the interpretation of the flight instruments and the application of this information to the controlling of the aircraft. Through the use of instruments, the position of the aircraft is reliably presented and the task is to determine this position and to apply corrective action if it is in error.

"Attitude instrument flying can be divided into three major components -- instrument coverage, instrument interpretation, and aircraft control. Instrument coverage is known as the ability to cross-check the panel and being able to integrate the information. The more frequent the check of each instrument the more proficient the pilot. Therefore it is advisable to check as rapidly as possible and never to linger over one instrument any longer than it is necessary to read and interpret it. The cross-check can only be developed through continual practice. It will be very difficult in the initial stages to cross-check and not to linger over one instrument when it is in error. The errors in developing a cross-check that many of you will fall into are: (a) omitting an instrument from the check completely, (b) concentrating on one instrument at the expense of the others, and (c) fixating on the wrong instrument. It is imperative that each one of you develop a scan-pattern. The technique for doing this is of individual concern. An example of fixation on the wrong instrument would be when during a power change, concentration on the manifold pressure gauge would result in careless performance of the flight instruments that are necessary for the controlling of the aircraft during the power change.

"The second component of attitude instrument flying is instrument interpretation or the ability to read an instrument and determine what information it is trying to impart to the pilot. There will be, in the initial stages of this experiment, much time spent in interpretation and reading of the necessary instruments. Proper instrument interpretation contributes to efficient instrument flying.

"Instrument flying for precision is a function of the ability of the pilot to interpret the instruments and apply necessary corrections. The instruments should always be interpreted in relation to the attitude of the

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aircraft; that is, the instrument should give the pilot some understanding as to what the aircraft is doing. The best way for you to become proficient is to gain an understanding of how the instrument is read and the principle of the operation of each instrument.

"Also, it will be necessary for you to understand the primary and supporting instruments for each maneuver that you will perform, as this knowledge of which instruments to scan will make the task seem far less difficult. An example of this is: if the position of the wings is to be determined, the attitude indicator is the primary instrument and the heading indicator supporting. This is true because the heading of an aircraft will change whenever it is in a bank.

"The third component of attitude flying is the actual control of the aircraft. Control movements necessary to produce a given attitude or correction should be small but positive. With practice you will be able to establish set attitudes with certain control movements and then through a continual cross-check refine the initial attitude and thus be able to precisely control the aircraft. Aircraft control is broken down into four coordinate steps: (a) pitch control, (b) bank control, (c) power control, and (d) trim.

"Pitch control, as seen in the film, is controlling the fuselage about the lateral axis through forward and backward forces on the stick. This movement controls the elevators which in turn determine the amount of pitch. The first step in the control of pitch attitude is to interpret the attitude of the aircraft from the appropriate instruments and then to exert control pressures on the elevator to effect the desired pitch attitude with continual reference to the instruments.

"Bank control is achieved by controlling the angle of the wing in relation to the earth's surface. The sequence in controlling the bank is much the same as that of the pitch. Interpret the bank attitude of the aircraft from the attitude indicator and the heading indicator and then by exerting control pressure on the stick either left or right activate the ailerons until the desired bank is attained.

"Power control is accomplished with the throttle utilizing predetermined settings that under normal circumstances will give the desired

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airspeeds. The proper power setting is indicated on the manifold pressure gauge which gives a direct reading of the fuel/air pressure in the intake manifold in inches of mercury. The airspeed indicator will aid in the proper use of the throttle for the desired airspeeds and attitudes. Power control is very critical for precise instrument flying. However, do not spend too much time in setting the power by the manifold pressure gauge alone but check the other instruments, and with the aid apply the final precise adjustments as deemed necessary.

"Trim control is achieved by relieving all possible control pressures after the desired attitude has been attained. Precision instrument flying is very difficult when the pressures are being held manually. For example, if the trainer is trimmed for a climb and you are flying straight and level, the least little relaxation on the controls will result in the aircraft immediately assuming a climbing attitude and a resultant loss in precision. Always relieve control pressures after each attitude change through the trim tabs. Proper control of the trim will make your task easier and also result in more accurate control of the aircraft.

"Pitch, bank, power, and trim control are to be performed in a coordinated manner and should not be thought of as separate and progressive steps. In this discussion they were broken down in this manner so as to facilitate the explanation of each of the necessary control problems that will confront you.

"It is important that you relax as completely as possible while flying the trainer. If you are tense, the control movements will be erratic and abrupt. Also tenseness may cause you to hold control pressures against that of the trim, which will tend to make the task more difficult and lessen the accuracy of flight control."

Definitions Pertinent to Flight

The following definitions were presented to the subjects:

1. Straight and level flight -- flight on a constant heading with the wings level, neither gaining nor losing altitude.
2. Climb -- the gaining of altitude.
3. Descent -- the loss of altitude.

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4. Standard climb -- climb at 1000 feet per minute, 110 MPH and 30 inches.
5. Standard descent -- descent at 1000 feet per minute, 90 MPH.
6. Standard turn -- a turn at the rate of 3 degrees per second, 20 degree bank.
7. Normal cruise -- level flight at 140 MPH, 26 inches.
8. Slow flight -- level flight at 90 MPH, landing gear and flaps down, 22 inches.
9. Glide -- descent at 110 MPH, landing gear and flaps up, 10 inches, 500 feet per minute.
10. Level flight -- flight which neither gains nor loses altitude.
11. Descending turn -- loss of altitude while turning at a standard rate.
12. Climbing turn -- gaining altitude while turning at a standard rate.
13. Level turn -- a change of heading while maintaining level flight.

Demonstration and Explanation of the Flight Instruments

An explanation and demonstration of the flight instruments in relation to various maneuvers were presented using the instrument mock-up (Figure 17). One experimenter manipulated the instrument settings in response to the other experimenter's verbal programming of different maneuvers. As each maneuver was demonstrated, the primary and supporting pitch and bank instruments were pointed out. The maneuvers demonstrated were similar to those presented in the flight task. An outline for the demonstration is presented below:

Takeoff

Release parking brakes

Add throttle all the way forward (full throttle)

Ease stick slightly forward while adding throttle and at 90 MPH

ease stick back and establish a standard climbing attitude.

Maintain 90 - 110 MPH

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Hold heading

Power button down and landing gear up at 300 feet

Retard throttle at 110 MPH to 30 inches whenever that occurs

Hold airspeed at 110 by adjusting pitch attitude

Maintain power at 30 inches

Primary and secondary instruments

Straight climb

Maintain climb attitude

Maintain 110 MPH

Maintain Heading

Maintain 30 inches

Primary and secondary instruments

Climbing turn

Hold climbing attitude

Hold airspeed 110 MPH

Establish standard rate turn (15-degree bank at 110 MPH)

Maintain 30 inches

Check heading periodically and 6 degrees before desired heading start roll-out so that the heading will be right (takes 6 degrees to roll out)

Primary and secondary instruments

Level off

Ease nose over, keeping the wings level

Hold heading

Hold altitude

At 140 MPH retard throttle to 26 inches to maintain 140 MPH

Make necessary corrections to maintain straight and level flight

Move prop to cruise

Move mixture to cruise

Fuel Selector to left tank

Trim for normal cruise

Primary and secondary instruments

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Level turns

Establish standard rate turn (20-degree bank at 140 MPH)
Hold altitude
Hold bank
Maintain 26 inches (a slight decrease in airspeed will be noted)
Allow 6 degrees for roll-cut
After roll-out maintain straight and level
Primary and secondary instruments

Change to slow flight

Procedures checklist
Hold altitude (back pressure, slightly nose high attitude)
Hold heading
Hold wings level
After establishing 90 MPH maintain
Trim (explain importance)
Primary and secondary instruments

Descending turn

Retard throttle to 10 inches
Lower the nose to a standard descending attitude holding 90 MPH
Establish 15 degree turn, maintain until 6 degrees before
desired heading
Add power to 50 feet above desired altitude; level off at 90 MPH
Turn should finish at same time the descent is finished
Maintain 90 MPH in level-off
Primary and secondary instruments

Change to normal cruise

Procedures checklist
Hold heading, and altitude
Maintain airspeed at 140 MPH after it is established
Primary and secondary instruments

APPENDIX A**Straight descent**

Retard throttle 10 inches

Hold altitude by increase of back pressure until 110 MPH is attained; then maintain 110 MPH

Hold heading

Hold airspeed

Add power 150 feet above altitude maintaining attitude; level out at desired altitude at 140 MPH

Hold straight and level

Primary and secondary instruments

Landing check off list

Procedures checklist

Maintain heading and altitude. Airspeed after 90 MPH

Primary and secondary instruments

Procedure turn

45-degree turn as level turn

Timed leg (timing starts when wings level after 45 degree turn)

Straight and level at 90 MPH

Hold heading, altitude, airspeed, and manifold pressure

Time leg after the wings level for one minute and make 180-degree right turn

Make necessary corrections

180-degree right turn (as level turn)

Primary and secondary instruments

Final approach

Retard power to 15 inches

Maintain 90 MPH

Maintain heading

Level-off altitude 100 feet

Add power 50 feet above level-off

Level off at 90 MPH

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PERIOD TWO

The second training period emphasized procedures training, although there was also a review of the information presented in the first period. Subject participation was introduced during the latter half of the second period. The period began with a study of the procedural checklists, using the photographic cockpit mock-up (Figure 18) for demonstration.

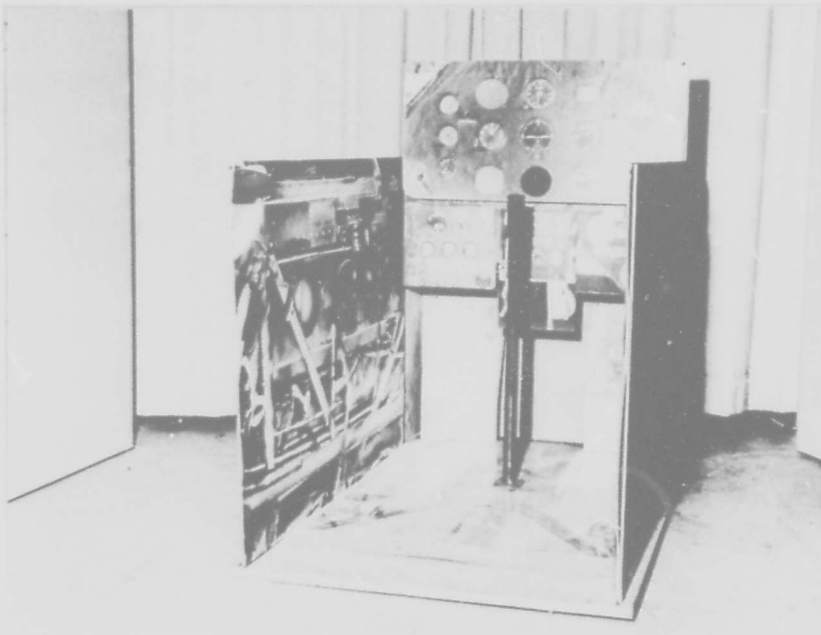


Figure 18. Photographic mock-up of SNJ OFT cockpit used in academic training.

Experimenter No. 2 was seated in the cockpit, the subjects were grouped around the mock-up, and the experimenter No. 1 was stationed at the front of the mock-up with the checklist cards. As experimenter No. 1 explained each item on the checklists, experimenter No. 2 demonstrated the movements necessary to perform the item.

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The second half of the period was spent on three areas, and all subjects spent equal time on each:

(a) The checklists were presented singly for a timed interval. The subjects were then asked to record on paper as many items as they could remember. An immediate review then was held for each checklist.

(b) Various conditions of flight were set up on the instrument mock-up panel and the subjects were asked to record on paper what they saw and what control movements would be necessary to return to normal flight. The condition and solution was explained by the experimenter after each presentation.

(c) Each subject was seated in the photographic cockpit mock-up for a common timed interval and was asked to locate each control in the cockpit pertinent to the study. As each subject had his turn, the remaining subjects observed. Assistance was given as needed.

The checklist cards had the procedures printed on large poster board material. The twelve cards for the procedural sequences were:

Cockpit check

- Fuel selector off
- Flaps up
- Landing gear down
- Trim set for takeoff
- Throttle closed
- Mixture idle cut off
- Prop low RPM
- Carburetor heat cold
- Battery switch off
- Mag switch off
- Check instruments
- Controls free and easy

Starting engine

- Set parking brakes
- Fuel selector right tank

APPENDIX A

Throttle cracked
Mixture full rich
Prop low RPM
Wobble pump
Prime
Prop clear
Battery switch on
Energize
Engage
Mag switch on both
After start -- prop high RPM

Engine run-up

Brakes
Stick back
Throttle to 26 inches
Prop low RPM
Prop high RPM
Mixture cruise
Mixture full rich
Throttle to 30 inches
Mag check
Carburetor heat checked
Oil shutters checked
Throttle closed

Takeoff check

Power button
Flaps up
Landing gear down
Fuel selector reserve
Fuel gauges checked
Trim set for takeoff
Mixture full rich

APPENDIX A

Prop high RPM
 Tail wheel locked
 Carburetor heat cold
 Oil cooler open
 Primer locked

Takeoff and climb

Release parking brakes
 Throttle full forward
 Stick forward Together
 Stick back at 100 - 110 MPH
 Set up climbing attitude
 Power button
 Landing gear up 300 - 500 feet
 Throttle to 30 inches at 110 MPH

Level off from climb

Stick forward to stop climb
 Maintain level off altitude
 Throttle to 26 inches at 140 MPH
 Prop to cruise
 Mixture to cruise
 Fuel to left tank
 Trim for cruise

Change to slow flight 90 MPH

Throttle to 19 inches
 Prop high RPM
 Mixture full rich
 Power button
 Landing gear down
 Maintain altitude
 Flaps down at 110 MPH
 Throttle to 22 inches at 90 MPH
 Trim for slow flight

APPENDIX A**Change to normal cruise 140 MPH**

Power button
Landing gear up
Throttle to 29 inches
Flaps up
Maintain altitude
Throttle to 26 inches at 140 MPH
Prop to cruise
Mixture to cruise
Trim for cruise

Landing check-off list

Fuel on reserve
Throttle to 19 inches
Prop high RPM
Mixture full rich
Power button
Landing gear down
Maintain altitude
Flaps down at 110 MPH
Throttle to 22 inches at 90 MPH
Check landing gear override
Trim for slow flight

Engine shut-down

Set parking brakes
Throttle closed
Prop low RPM
Mixture idle cut-off
Mag switch off
Battery switch off
Fuel selector off

APPENDIX A

Prop overspeed emergency

Close throttle -- glide

Mixture full rich

Prop low RPM

Wobble pump

Pull nose up

when light goes out:

Push nose down

Prop cruise

Throttle to 26 inches

Mixture cruise

Level off at 140 MPH

Fuel warning emergency

Crack throttle -- glide

Fuel to reserve

Mixture full rich

Prop high RPM

Wobble pump

When light goes out:

Throttle to 26 inches

Prop cruise

Mixture cruise

Level off at 140 MPH

APPENDIX B

FLIGHT TASK INSTRUCTIONS

- (a) "How do you read me? (Reply from subject: Loud and clear)
During this hop you will receive instructions to perform different maneuvers. It is important that you exert a constant effort to fly the trainer as instructed and correct any errors as indicated by the instruments. Remember to scan all the instruments continuously. When an emergency occurs, take corrective action immediately. Your call will be 'Navy One'.
- (b) "Navy one, you are cleared to takeoff and climb on a heading of zero degrees. At 2000 feet begin a 180-degree LEFT climbing turn. At 3000 feet begin a 180-degree RIGHT climbing turn. After completing the turns, continue climbing to 5000 feet. Level off at 5000 feet, 140 miles per hour, heading zero degrees, and maintain straight and level flight. Begin your takeoff NOW.
- (c) "Navy one, you are to make a LOW VISIBILITY PROCEDURE TURN. This consists of a 90-degree RIGHT turn followed immediately by a 270-degree LEFT turn. Use a 20-degree bank and maintain 5000 feet. Your final heading will be 180 degrees. Begin your turn NOW.
- (d) "Navy one, you are to change to SLOW FLIGHT of 90 miles per hour. Maintain 5000 feet and a heading of 180 degrees. Begin NOW.
- (e) "Navy one, you are to make a 360-degree DESCENDING RIGHT TURN. Use a 15-degree bank and maintain 90 miles per hour throughout the maneuver. Level off at 3000 feet and 90 miles per hour. Begin NOW.

APPENDIX B

- (f) "Navy one, you are to change to **NORMAL CRUISE** of 140 miles per hour. Maintain 3000 feet and a heading of 180 degrees. Begin **NOW**.
- (g) "Navy one, you are to **GLIDE TO** 1000 feet, maintaining 110 miles per hour and a heading of 180 degrees. Level off at 1000 feet, 140 miles per hour and maintain straight and level flight. Begin your glide **NOW**.
- (h) "Navy one, turn to a heading of 225 degrees **NOW**. (Not scored)
- (i) "Navy one, you are to maintain 1000 feet and a heading of 225 degrees, and go through the **LANDING CHECKOFF LIST**. Begin the check **NOW**.
- (j) "Navy one, you are to execute a **STANDARD PROCEDURE TURN**. This consists of a 45-degree left turn to a heading of 180 degrees. Begin timing a one minute straight and level leg at the completion of this turn. At the end of one minute, make a 180-degree **RIGHT TURN** to a heading of zero degrees. Maintain 1000 feet and 90 miles per hour. Begin now.
- (k) "Navy one, you are to begin a **FINAL APPROACH** to landing. Maintain 90 miles per hour and a heading of zero degrees. Level off at 100 feet and 90 miles per hour. Begin your approach **NOW**.
- (l) "Navy one, go through the **ENGINE SHUTDOWN** procedure. Begin **NOW**.
- (m) "Navy one, open the canopy and climb out."

APPENDIX C

DATA SHEETS FOR PERFORMANCE RECORDING

APPENDIX C

<u>ENGINE STARTING</u>		Error	No Error
Set parking brakes			
Fuel RIGHT TANK			
Throttle CRACKED			
Mixture FULL RICH			
Prop in LOW RPM			
Actuate WOBBLE PUMP			
PRIME engine			
Prop CLEAR (call out)			
Battery switch ON			
Energize			
Engage			
Mag. on BOTH			
After engine starts. prop to HIGH RPM			

<u>COCKPIT CHECK</u>		Error	No Error
Fuel OFF			
Flaps UP			
Landing gear DOWN			
Trim set for TAKE OFF			
Throttle CLOSED			
Mixture IDLE CUT OFF			
Prop in LOW RPM			
Carburetor heat COLD			
Battery switch OFF			
Mag. switch OFF			
Check instruments (Points to each)			
Controls free and easy (Move stick and rudder)			

APPENDIX C

TAKE OFF CHECKLIST

	Error	No Error
Power button		
Flaps UP		
Landing gear DOWN		
Fuel selector to RESERVE		
Fuel gauges checked		
Trim for TAKE OFF		
Mixture FULL RICH		
Prop HIGH RPM		
Tail wheel LOCKED		
Carburetor heat COLD		
Oil cooler shutters OPEN		
Primer LOCKED		

ENGINE RUN UP

	Error	No Error
Brakes		
Stick back		
Throttle to 26"		
Prop to LOW RPM		
Prop to HIGH RPM		
Mixture to CRUISE		
Mixture to FULL RICH		
Throttle to 30"		
Mag check: BOTH-LEFT-BOTH		
BOTH-RIGHT-BOTH		
Carburetor heat check		
Oil shutters check		
Throttle CLOSED		

APPENDIX C

TAKE OFF AND CLIMB TO 2000 FEET

Release parking brakes

Throttle Full Forward

Break ground at 100 mph

Power button)	Min 300'
Landing gear UP)	Max. 500'

Throttle to 30" at 110 mph

Manifold pressure at 1000'

START AIRSPEED AND HEADING SCORING AT 500 FEET

Error	No Error	AIRSPEED (110 mph)	HEADING (000°)
		10	
		20	
		30	
		40	
		50	
		60	
		70	
		80	
		90	

APPENDIX C

180° LEFT CLIMBING TURN

Manifold pressure at 2000'

Altitude at start of turn

Error	No Error

Initial bank direction

BANK (15°)

10

20

30

40

50

60

AIRSPEED (110 mph)

Error	No Error

Roll out bank direction

Roll out heading

--

180° RIGHT CLIMBING TURN

Manifold pressure at 3000'

Altitude at start of turn

Error	No Error

Initial bank direction

BANK (15°)

10

20

30

40

50

60

AIRSPEED (110 mph)

Error	No Error

Roll out bank direction

Roll out heading

--

APPENDIX C

STRAIGHT CLIMB FOR ONE MINUTE

Manifold pressure
at 4000'

--

Climb from 4000' up:

AIR SPEED (110) HEADING (000°)

10 20 30 40 50 60

Level off altitude

--

Manifold pressure
at 5000'

--

LEVEL OFF AT 5000 FEET

ALTITUDE (5000') HEADING (000°)

10 20 30 40 50 60

Error No Error

Throttle to 26" at 140 mph

Prop to CRUISE

Mixture to CRUISE

Fuel to LEFT TANK

Trim for CRUISE

APPENDIX C

LOW VISIBILITY PROCEDURE TURN

90° Right Turn Error No Error

Initial bank direction

Roll out bank direction

Roll out heading

270° Left Turn

Initial bank direction

Roll out bank direction

Bank	Altitude
10	
20	
30	
40	
50	
60	

Roll out heading

TWO MINUTE STRAIGHT AND LEVEL LEG

Altitude (5000')	Airspeed (140 mph)	Heading (000°)
10		
20		
30		
40		
50		
60		
70		
80		
90		
100		
110		
120		

APPENDIX C

CHANGE TO NORMAL CRUISE

Power button

Landing gear UP

Throttle to 29"

Flaps UP

Throttle to 26" at 140 mph

Prop to CRUISE

Mixture to CRUISE

Trim for CRUISE

Error No Error

10	Altitude (3000')	Heading (180°)
20		
30		
40		
50		
60		
70		
80		
90		
100		
110		
120		

APPENDIX C

GLIDE TO 1000'

Throttle to 10"
Establish glide

Error	No Error

Throttle advanced at +150"
Throttle advanced to 26"

Level off altitude (1000')

--

Heading (180°)												
	10	20	30	40	50	60	70	80	90	100	110	120

APPENDIX C

<u>STANDARD PROCEDURE TURN</u>																																				
<p style="text-align: center;"><u>45° Left Turn</u></p> <p style="text-align: center;">Initial bank direction</p> <p style="text-align: center;">Roll out bank direction</p> <p style="text-align: center;">Roll out heading (180°)</p> <p style="text-align: center;"><u>One Minute Timed Leg</u></p> <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 20%; text-align: center;">Altitude (1000')</td> <td style="width: 20%; text-align: center;">Airspeed (90 mph)</td> <td style="width: 20%; text-align: center;">Heading (180°)</td> </tr> <tr> <td style="text-align: center;">10</td> <td style="text-align: center;">10</td> <td style="text-align: center;">10</td> </tr> <tr> <td style="text-align: center;">20</td> <td style="text-align: center;">20</td> <td style="text-align: center;">20</td> </tr> <tr> <td style="text-align: center;">30</td> <td style="text-align: center;">30</td> <td style="text-align: center;">30</td> </tr> <tr> <td style="text-align: center;">40</td> <td style="text-align: center;">40</td> <td style="text-align: center;">40</td> </tr> <tr> <td style="text-align: center;">50</td> <td style="text-align: center;">50</td> <td style="text-align: center;">50</td> </tr> <tr> <td style="text-align: center;">60</td> <td style="text-align: center;">60</td> <td style="text-align: center;">60</td> </tr> </table> <p style="text-align: center;">Length of leg (sec.)</p>	Altitude (1000')	Airspeed (90 mph)	Heading (180°)	10	10	10	20	20	20	30	30	30	40	40	40	50	50	50	60	60	60	<p style="text-align: center;"><u>180° Right Turn</u></p> <p style="text-align: center;">Initial bank direction</p> <p style="text-align: center;">Roll out bank direction</p> <p style="text-align: center;">Roll out heading (360°)</p> <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 20%; text-align: center;">Bank (15°R)</td> <td style="width: 20%; text-align: center;">Altitude (1000')</td> </tr> <tr> <td style="text-align: center;">10</td> <td style="text-align: center;">10</td> </tr> <tr> <td style="text-align: center;">20</td> <td style="text-align: center;">20</td> </tr> <tr> <td style="text-align: center;">30</td> <td style="text-align: center;">30</td> </tr> <tr> <td style="text-align: center;">40</td> <td style="text-align: center;">40</td> </tr> <tr> <td style="text-align: center;">50</td> <td style="text-align: center;">50</td> </tr> <tr> <td style="text-align: center;">60</td> <td style="text-align: center;">60</td> </tr> </table>	Bank (15°R)	Altitude (1000')	10	10	20	20	30	30	40	40	50	50	60	60
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APPENDIX C

ENGINE SHUTDOWN

- Set parking brakes
- Throttle CLOSED
- Prop to LOW RPM
- Mixture to IDLE CUT-OFF
- Mag switch OFF
- Battery switch OFF when
airspeed at zero
- Fuel selector OFF

FINAL APPROACH TO LANDING

Airspeed	Heading
10	
20	
30	
40	
50	
60	
70	
80	
90	

- Throttle to 15" at start
of approach
- Throttle advanced at +50'
- Throttle advanced to 22"
- Level off altitude (100')

APPENDIX C

FUEL WARNING EMERGENCY

Throttle CRACKED

Establish glide (110 mph)

Fuel to RESERVE

Mixture to FULL RICH

Prop to HIGH RPM

Wobble pump

Turn light off here:

Throttle to 26"

Prop to CRUISE

Mixture to CRUISE

Level off at 140 mph

Error

No Error

Minimum airspeed

--

Maximum heading deviation

--

Altitude loss

--

Time to complete sequence

--

(Navy One: change fuel to left tank)

APPENDIX C

PROP OVERSPEED EMERGENCY

Throttle CLOSED

Establish glide (110 mph)

Mixture to FULL RICH

Prop to LOW RPM

Wobble pump

Pull nose UP

Turn light off here:

Push nose OVER

Prop to CRUISE

Throttle to 26"

Mixture to CRUISE

Level off at 140 mph

Error No Error

Minimum airspeed

--

Maximum heading deviation

--

Altitude loss

--

Time to complete sequence

--

APPENDIX D

SCORING RULES

All the procedural sequences were scored in the same manner. Each list of procedures on the scoring sheets consisted of a list of items and an error, no-error column. As the subject performed the items and no error was made, a check was placed in the no-error column. However, if the subject omitted an item, a check was placed in the error column. A missed item that was subsequently completed had a checkmark placed in the no-error column, provided the item was completed prior to its corresponding critical point in the sequence. For example, the Engine Starting procedure called for the parking brakes to be set as Step No. 1, but as long as the parking brakes were set prior to engaging the engine, the item was considered correct.

The values of pertinent flight parameters were read every ten seconds during a maneuver.

Takeoff and climb

Scoring period:	Scoring starts as soon as the subject begins going through the list. Flight parameters are scored from the altitude of 500 feet until the aircraft reaches 2000 feet or one and one-half minutes, which ever occurs first.
Release parking brakes:	Error, no-error item. Scored as an error if not done prior to application of throttle.
Throttle full forward:	Error, no-error item. Scored as an error if throttle is not advanced full forward
Break ground at 100 MPH:	Error, no-error item. Scored as an error if the subject does not try to take the trainer off within plus or minus 5 MPH.

APPENDIX D

Power Button: Error, no-error item. Scored as an error if the power button is not depressed between 300 feet and 500 feet.

Landing gear up: Error, no-error item. Scored as an error if the landing gear is pulled up before 300 feet or not pulled up by 500 feet.

Throttle to 30 inches: Error, no-error item. When 110 MPH is attained at a standard climbing attitude the power should be retarded to 30 inches. An error is scored if the power is not adjusted within plus or minus 1 inch.

Airspeed: Record the airspeed at 10-second intervals.

Heading: Record the deviations in heading from 000 degrees at 10-second intervals during the scoring period.

180-degree left climbing turn

Scoring period: The point where there is positive control action in the correct direction, other than to correct an error, will define the start of the turn. Scoring period will last for one minute or until the trainer has completed the turn, whichever occurs first.

Altitude at the start of the turn: Record the altitude at which the positive control movement occurred.

Initial bank direction: Error, no-error item. Any movement opposite to that required to make the trainer respond in the manner prescribed will be scored as an error.

Angle of bank: Record the angle of bank at 10-second intervals.

Airspeed: Record the airspeed at 10-second intervals.

APPENDIX D

Roll-out bank direction: Error, no-error item. Any movement opposite to that required to level the wings as the roll-out heading is approached will be scored as an error.

Roll-out heading: Record the heading at the point where the wings become level after the trainer has turned at least 90 degrees.

180-degree right climbing turn

The items for the right turn are scored the same as the items for the 180-degree left climbing turn.

Straight climb for one minute

Scoring period: For one minute after passing through 4000 feet or until 5000 feet is reached, whichever occurs first.

Airspeed: Record the airspeed at 10-second intervals.

Heading: Record the deviation in heading from 000 degrees at 10-second intervals.

Level off at 5000 feet

Scoring period: For one minute after reaching level-off altitude.

Level-off altitude: Record the altitude at the point where the rate of climb reaches zero or a reverse rate.

Altitude: Record deviation in altitude from 5000 feet at 10-second intervals.

Heading: Record the deviations in heading from 000 degrees at 10-second intervals.

Throttle to 26 inches at 140 MPH: Error, no-error item. Throttle is to be reduced within the range of ± 5 MPH of 140 MPH.

Prop to cruise: Error, no-error item. Scored as an error if done before reducing throttle to 26 inches.

Mixture to cruise: Error, no-error item. Scored as an error if done before reducing the throttle to 26 inches.

Fuel to left tank: Error, no-error. Scored as an error if done prior to level-off, or not completed during scoring period.

Trim set for cruise: Error, no-error item. An error is recorded if the trim is not adjusted to the cruise position during the scoring period.

APPENDIX D

Two-minute straight and level

- Scoring period: Two minutes from the time that the subject receives instructions to hold 000 degrees, 5000 feet, and 140 MPH.
- Altitude: Record the deviation in altitude from 5000 feet at 10-second intervals.
- Airspeed: Record the airspeed at 10-second intervals.
- Heading: Record the deviation in heading from 000 degrees at 10-second intervals.

Low visibility procedure turn (90-degree right turn)

- Scoring period: For one minute, or until the turn is completed, whichever occurs first.
- Initial bank direction: Error, no-error item. Any movement that is opposite to that required to make the trainer respond in the prescribed manner will be scored as an error.
- Roll-out bank direction: Error, no-error item. Any movement opposite to that required to level the wings as the roll-out heading is approached will be scored as an error.
- Roll-out heading: Record the heading at the point where the wings become level after the trainer has turned at least 45 degrees.

Low visibility procedure turn (270-degree left turn)

- Scoring period: For one minute from the initial bank movement starting the 270-degree turn, or until the turn is completed, whichever occurs first.
- Initial bank direction: Error, no-error item. Any movement that is opposite to that required to make the trainer respond in the prescribed manner will be scored as an error.
- Angle of bank: Record the angle of bank at 10-second intervals.
- Altitude: Record the deviation in altitude from 5000 feet at 10-second intervals.
- Roll-out bank direction: Error, no-error item. Any movement opposite to that required to level the wings as the roll-out heading is approached will be scored as an error.

APPENDIX D

Roll-out heading:	Record the heading at the point where the wings become level after the trainer has turned at least 135 degrees.
<u>Change to slow flight</u>	
Scoring period:	For two minutes starting with the order to begin.
Throttle to 19 inches:	Error, no-error item. Throttle must be reduced to ± 1 inch of 19 inches manifold pressure.
Prop to low pitch:	Error, no-error item.
Mixture to full rich:	Error, no-error item.
Power button:	Error, no-error item. Scored as an error if the landing gear is lowered before the power button is pushed.
Landing gear down:	Error, no-error item.
Flaps down at 110 MPH:	Error, no-error item. Scored as an error if the flaps are not lowered within ± 5 MPH.
Throttle to 22 inches at 90 MPH:	Error, no-error item. An error is scored if the throttle is not advanced within ± 5 MPH from 90 MPH.
Trim for slow flight:	Error, no-error item. Scored an error if the trim is not utilized sometime during the procedure.
Altitude:	Record the deviations in altitude from 5000 feet at 10-second intervals.
Heading:	Record the deviations in heading from 180 degrees at 10-second intervals.

APPENDIX D

360-degree descending right turn (lose 2000 feet)

Scoring period:	For two minutes starting with the order to begin, or until the turn or level off is completed, whichever occurs first.
Throttle to 10 inches:	Error, no-error item. Must be done first.
Initial bank direction:	Error, no-error item. Any movement that is opposite to that required to make the trainer respond in the prescribed manner will be scored as an error.
Throttle added at +50 feet:	Error, no-error item. Scored as an error if throttle is not advanced 50 feet above level off altitude.
Throttle added to 22 inches:	Error, no-error item. Throttle must be within ± 1 inch of 22 inches.
Roll-out bank direction:	Error, no-error item. Any movement opposite to that required to level the wings as the roll-out heading is approached will be scored as an error.
Roll-out heading:	Record the heading at the point that the wings are level after the trainer has turned 270 degrees.
Level off altitude:	Record the altitude at the point where the vertical speed indicator reaches zero or a reverse rate.
Angle of bank:	Record the angle of bank at 10-second intervals.
Airspeed:	Record the airspeed at 10-second intervals.

APPENDIX D

Change to normal cruise

- Scoring period: For two minutes starting with the order to begin.
- Power button: Error, no-error item. Scored as an error if not depressed prior to actuating landing gear or flap controls.
- Landing gear up: Error, no-error item.
- Throttle to 29 inches: Error, no-error item. Scored as an error if the subject omits, or errs in throttle adjustment of ± 1 inch.
- Flaps up: Error, no-error item. Scored as an error if retracted prior to adding throttle.
- Throttle to 26 inches at 140 MPH: Error, no-error item. Scored as an error if throttle is not reduced to 26 inches by ± 5 MPH of 140 MPH. Throttle must be adjusted within ± 1 inch of 26 inches.
- Prop to cruise: Error, no-error item. Scored as an error if done prior to reducing throttle to 26 inches.
- Mixture to cruise: Error, no-error item. Scored as an error if done prior to reducing throttle to 26 inches.
- Trim for cruise: Error, no-error item. An error is scored if the subject fails to trim during the scoring period.
- Heading: Record the deviations in heading from 180 degrees at 10-second intervals.
- Altitude: Record the deviations in altitude from 3000 feet at 10-second intervals.

APPENDIX D

Glide to 1000 feet

- Scoring period: For two minutes starting from the order to begin, or until 1000 feet is reached, whichever occurs first.
- Throttle to 10 inches: Error, no-error item. Scored as an error if not done first, or the throttle setting is not within ± 1 inch of 10 inches.
- Establish glide: Error, no-error item. Scored as an error if the descent is started prior to reducing the airspeed to 115-105 MPH.
- Throttle advanced at + 150 feet: Error, no-error item. Scored as an error if the throttle is not advanced at 150 feet above the level-off altitude.
- Throttle to 26 inches: Error, no-error item. Scored as an error if the throttle is not adjusted to within ± 1 inch of 26 inches.
- Level-off altitude: Record the altitude at the point where the rate of descent reached zero or a reversed rate.
- Heading: Record the deviations in heading from 180 degrees at 10-second intervals.

Landing checkoff list

- Scoring period: For two minutes starting from the order to begin.
- Fuel on reserve: Error, no-error item. Scored as an error if the fuel selector is not set to Reserve by the end of the scoring period.

(The next eight procedural items of this maneuver are identical to the eight procedures in the Change to Slow Flight maneuver.)

APPENDIX D

Check landing gear override: Error, no-error item. Scored as an error if the gear override is not actuated by the end of the scoring period.

Altitude: Record the deviations in altitude from 1000 feet at 10-second intervals.

Heading: Record the deviations in heading from 225 degrees at 10-second intervals.

Standard procedure turn (45-degrees left turn to 180 degrees)

Scoring period: For one minute starting from the point when the roll-out heading is reached.

Altitude: Record the deviations in altitude from 1000 feet at 10-second intervals.

Airspeed: Record the airspeed at 10-second intervals.

Heading: Record the deviations in heading from 180 degrees at 10-second intervals.

Length of leg: Record the time in seconds from the point where the roll-out heading is reached until the initial bank movement is made for the 180-degree right turn.

Standard procedure turn (180 degrees right turn to 000 degrees)

Scoring period: For one minute starting from the initial bank movement or until the turn is completed, whichever occurs first.

Initial bank direction: Error, no-error item. Any movement that is opposite to that required to make the trainer respond in the prescribed manner will be scored as an error.

Bank: Record the angle of bank at 10-second intervals.

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Altitude:	Record the deviations in altitude from 1000 feet at 10-second intervals.
Roll-out bank direction:	Error, no-error item. Any movement opposite to that required to level the wings as the roll-out heading is approached will be scored as an error.
Roll-out heading:	Record the heading at the point where the wings become level when approaching the instructed roll-out heading of 000 degrees.
<u>Final approach to landing</u>	
Scoring period:	For 90 seconds starting from the order to begin, or until the throttle is advanced to begin the level-off, whichever occurs first.
Throttle to 15 inches at start of approach:	Error, no-error item. Throttle must be reduced to 15 inches within \pm 1 inch, and the nose lowered to maintain 90 MPH.
Airspeed:	Record the airspeed at 10-second intervals.
Heading:	Record the deviations in heading from 000 degrees at 10-second intervals.
Throttle advanced:	Error, no-error item. Throttle must be advanced at 50 feet above the level off altitude of 100 feet.
Throttle to 22 inches:	Error, no-error item. Throttle must be properly adjusted at 22 inches.
Level-off altitude:	Record the altitude at the point where the rate of descent reaches zero or a reversed rate.

APPENDIX D

Engine shutdown

- Set parking brakes: Error, no-error item. Must be done first.
- Throttle closed: Error, no-error item. After throttle is closed, the nose should be lowered so that the trainer may drop into the straps. Scored on closing throttle only.
- Prop low RPM: Error, no-error item. Scored as an error if done prior to putting the mixture in the idle cut-off position.
- Mixture idle cut-off: Error, no-error item.
- Mag switch off: Error, no-error item.
- Battery switch off when airspeed at zero: Error, no-error item. Scored as an error if done prior to allowing the airspeed to drop to zero (trainer requirement).
- Fuel selector off: Error, no-error item.
- Prop overspeed emergency (items to be performed while warning light is on)
- Close throttle: Error, no-error item. Must be done first when the prop overspeed light comes on.
- Establish glide: (110 MPH) Error, no-error item. Altitude must be maintained until the airspeed drops off to 110 MPH, then the nose should be lowered to maintain the gliding airspeed of 110 MPH.
- Prop low RPM: Error, no-error item.

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Mixture full rich: Error, no-error item.

Wobble pump: Error, no-error item. Must be done together with the next item.

Pull nose up: Error, no-error item. While actuating the wobble pump, the nose should be raised to a slightly nose-high attitude.

Prop overspeed emergency (items to be performed after warning light goes off)

Push nose over: Error, no-error item. The nose should be returned to a nose-down glide attitude.

Prop to cruise: Error, no-error item. Must be done prior to adding the throttle, and only up to the cruise position.

Throttle to 26 inches: Error, no-error item. Must be adjusted correctly at 26 inches.

Mixture to cruise: Error, no-error item.

Level-off at 140 MPH: Error, no-error item. After adding the throttle up to 26 inches, the nose must be held down until 140 MPH is reached. Then a level-off is made, maintaining whatever altitude is indicated.

Minimum airspeed: Record the minimum airspeed during the scoring period.

Maximum heading deviation: Record the number of degrees the heading deviates from the heading held at the start of the emergency.

Altitude lost: Record the number of feet of altitude lost while completing the entire sequence.

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Time to complete the sequence: This is the scoring period. Record the time in seconds from the time the prop overspeed light is turned on until the entire sequence for resolving the emergency has been completed.

Fuel warning emergency (items to be performed while warning light is on)

Throttle cracked: Error, no-error item. Must be done first when the fuel warning light comes on.

Establish glide: (110 MPH) Error, no-error item. Altitude must be maintained until the airspeed drops off to 110 MPH, then the nose should be lowered to maintain the gliding airspeed of 110 MPH.

Fuel to reserve: Error, no-error item. Scored as an error if not done prior to using wobble pump.

Mixture full rich: Error, no-error item.

Prop high RPM: Error, no-error item.

Wobble pump: Error, no-error item. Must be actuated until the light goes out.

Fuel warning emergency (items to be performed after warning light is off)

Throttle to 26 inches: Error, no-error item. Must be adjusted correctly at 26 inches.

Prop to cruise: Error, no-error item.

Mixture to cruise: Error, no-error item.

Level-off at 140 MPH: Error, no-error item. After adding the throttle up to 26 inches, the nose must be held down until 140 MPH is reached. Then a level-off is made, maintaining whatever altitude is indicated.

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Minimum airspeed:	Record the minimum airspeed during the scoring period.
Maximum heading deviation:	Record the number of degrees the heading deviates from the heading at the start of the emergency.
Altitude lost:	Record the number of feet of altitude lost while completing the entire sequence for the emergency.
Time to complete the sequence:	This is the scoring period. Record the time in seconds from the time the fuel warning light is turned on until the entire sequence for resolving the emergency has been completed.

APPENDIX E

DETAILED DATA ON PROCEDURAL SEQUENCES

APPENDIX E

TABLE 17

Percent retention loss for separate procedural sequences of
each procedures category

<u>Procedures Category</u>	<u>Group 10</u>	<u>Group 5</u>
STATIC Procedures		
Cockpit check	17.5	25.0
Engine starting	21.5	27.7
Engine run-up	26.9	30.0
Takeoff checklist	20.8	35.8
Engine shutdown	14.3	18.6
Total	20.9	28.2
DYNAMIC Procedures		
Takeoff	15.0	20.0
Level-off	18.0	8.0
Change to slow flight	8.8	13.8
360° desc right turn	0.0	6.7
Change to normal cruise	11.3	11.3
Glide	2.5	10.0
Landing checklist	13.0	4.0
Final approach	13.3	6.7
Total	11.1	10.2
EMERGENCY Procedures		
Prop Overspeed	20.0	27.3
Fuel Warning	13.0	12.0
Total	16.7	20.0
ALL Procedures	16.5	20.1

APPENDIX E

TABLE 18
Per cent correct on each trial for the four principal categories of procedures

Procedures Category	Group	Training Trials										Retention Trials			
		1	2	3	4	5	6	7	8	9	10	1	2	3	4
Static (57)*	10	56.3	64.0	73.5	78.4	85.8	87.4	91.9	93.9	94.6	96.1	75.3	85.8	94.6	95.8
	5	48.8	63.5	70.2	77.9	84.2						56.0	73.2	78.1	85.4
Dynamic(47)*	10	48.5	64.3	70.2	74.7	78.9	85.5	90.2	89.8	92.3	95.3	84.3	87.7	91.9	95.1
	5	39.6	55.5	58.9	70.0	74.5						64.3	75.1	80.0	82.8
Emergency(21)*	10	43.8	62.4	74.3	72.4	80.5	83.3	86.2	84.8	92.9	92.4	75.7	81.0	85.7	92.4
	5	42.4	50.0	61.4	64.3	72.4						52.4	68.6	75.2	81.9
All Procedures (125)*	10	51.3	63.8	72.4	76.0	82.3	86.0	90.3	90.8	93.4	95.2	78.7	85.7	92.1	95.0
	5	44.2	58.2	64.5	72.6	78.6						58.5	73.1	78.3	83.8

*Total number of items

APPENDIX E

TABLE 19
 Mean number of errors on each trial for separate static procedural sequences

Static Proced- ures	Total Possible	Training Trials							Retention Trials						
		1	2	3	4	5	6	7	8	9	10	1	2	3	4
<u>Group 10</u>															
Cockpit check	12	3.3	2.8	1.8	2.1	1.3	1.1	.6	.5	.6	.8	2.9	1.0	.6	.3
Engine starting	13	5.3	5.0	4.2	3.4	1.8	1.8	1.2	.7	.6	.6	3.4	3.2	.9	.9
Engine run-up	13	6.8	4.8	4.2	2.8	2.0	1.6	1.3	1.0	.6	.1	3.6	1.5	.7	.4
Take-off checklist	12	6.8	5.4	3.1	2.2	1.6	1.5	1.0	.9	.6	.3	2.8	1.7	.7	.4
Engine shutdown	7	2.7	2.5	1.8	1.8	1.4	1.2	.5	.4	.7	.4	1.4	.7	.2	.4
Total	57	24.9	20.5	15.1	12.3	8.1	7.2	4.6	3.5	3.1	2.2	14.1	8.1	3.1	2.4
<u>Group 5</u>															
Cockpit check	12	2.8	2.8	2.1	1.8	1.8	1.8	1.8	1.8	1.8	1.8	4.8	2.3	2.0	.8
Engine starting	13	7.1	4.4	4.3	2.8	2.5	2.5	2.5	2.5	2.5	2.5	6.1	4.7	3.2	2.8
Engine run-up	13	8.5	6.6	4.8	3.4	2.3	2.3	2.3	2.3	2.3	2.3	6.2	4.3	3.5	2.1
Takeoff checklist	12	7.4	4.4	4.2	3.0	1.4	1.4	1.4	1.4	1.4	1.4	5.7	2.4	2.5	1.4
Engine shutdown	7	3.4	2.6	1.6	1.6	1.0	1.0	1.0	1.0	1.0	1.0	2.3	1.6	1.3	1.2
Total	57	29.2	20.8	17.0	12.6	9.0	9.0	9.0	9.0	9.0	9.0	25.1	15.3	12.5	8.3

APPENDIX E

TABLE 20
Mean number of errors on each trial for separate dynamic procedural sequences

Dynamic Procedures	Total Possible	Training Trials						Retention Trials							
		1	2	3	4	5	6	7	8	9	10	1	2	3	4
Group 10															
Takeoff	6	3.4	2.8	2.0	1.4	1.4	1.0	.5	.3	.2	.1	1.0	.4	.6	.2
Level-off	5	3.5	1.7	1.8	1.7	1.3	1.2	.8	.7	.6	.3	1.2	1.0	.5	.3
Change to slow flight	8	3.3	1.8	1.1	1.1	.5	.7	.2	.2	.4	.2	.9	.9	.4	.3
360° desc right turn	3	2.1	1.4	1.1	1.2	.8	1.1	.4	.7	.4	.5	.5	.7	.5	.3
Change to normal cruise	8	2.8	2.0	2.6	2.6	2.0	.9	.8	1.2	.6	.3	1.2	1.2	.3	.3
Glide	4	2.3	1.4	.8	.7	1.2	.4	.4	.3	.1	.2	.3	.1	.2	.1
Landing checklist	10	5.4	4.4	4.1	2.6	2.4	1.3	1.3	1.3	1.2	.5	1.8	1.3	1.1	.8
Final approach	3	1.4	1.3	.5	.6	.3	.2	.2	.1	.1	.1	.5	.2	.2	.0
Total	47	24.2	16.8	14.0	11.9	9.9	6.8	4.6	4.8	3.6	2.2	7.4	5.8	3.8	2.3
Group 5															
Takeoff	6	3.8	3.1	2.7	2.8	1.2						2.4	1.4	1.0	.9
Level-off	5	3.2	2.1	2.0	1.7	1.4						1.8	1.7	1.2	.8
Change to slow flight	8	4.5	2.8	2.2	1.2	1.3						2.4	1.2	1.2	1.2
360° desc right turn	3	2.1	1.7	1.7	1.2	1.2						1.4	.8	1.2	1.0
Change to normal cruise	8	4.2	3.0	3.4	1.7	1.8						2.7	1.5	1.0	1.4
Glide	4	1.8	1.5	1.6	.9	.9						1.3	.7	.4	.3
Landing checklist	10	7.0	5.4	4.6	4.0	3.8						4.2	3.8	2.8	2.2
Final approach	3	1.8	1.3	1.1	.6	.4						.6	.6	.6	.3
Total	47	28.4	20.9	19.3	14.1	12.0						16.8	11.7	9.4	8.1

TABLE 21

Mean number of errors on each trial for separate emergency procedural sequences

Emergency Procedures	Total Possible	Training Trials					Retention Trials								
		1	2	3	4	5	6	7	8	9	10	1	2	3	4
<u>Group 10</u>															
Prop overspeed	11	6.2	4.5	3.0	3.8	2.6	2.6	2.0	2.4	1.3	1.5	3.7	2.6	2.2	1.5
Fuel warning	10	5.6	3.4	2.4	2.0	1.5	.9	.9	.8	.2	.1	1.4	1.4	.8	.1
Total	21	11.8	7.9	5.4	5.8	4.1	3.5	2.9	3.2	1.5	1.6	5.1	4.0	3.0	1.6
<u>Group 5</u>															
Prop overspeed	11	6.6	6.9	4.6	4.2	3.5						6.5	3.2	3.4	2.8
Fuel warning	10	5.5	3.6	3.5	3.3	2.3						3.5	3.4	1.8	1.0
Total	21	12.1	10.5	8.1	7.5	5.8						10.0	6.6	5.2	3.8

APPENDIX F

t TESTS FOR RELATED MEASURES OF THE MEAN DIFFERENCE
IN ERRORS BETWEEN FINAL TRAINING TRIAL AND FIRST RETENTION
TRIAL FOR SEPARATE PROCEDURAL SEQUENCES.

APPENDIX F

TABLE 22

t test of the mean difference in errors between final training trial
and first retention trial for static procedural sequences

Static Procedure	Group 10			Group 5		
	Mean Diff.	<u>t</u> *	Reliability of Diff.	Mean Diff.	<u>t</u> *	Reliability of Diff.
Cockpit check	2.1	4.7	<.01	3.0	6.1	<.01
Engine starting	2.8	5.5	<.01	3.5	7.7	<.01
Engine run-up	3.5	6.1	<.01	3.9	8.5	<.01
Takeoff checklist	2.5	5.5	<.01	4.2	7.3	<.01
Engine shutdown	0.9	3.9	<.01	1.3	3.6	<.01
All combined	7.8	2.8	.02>P>.01	15.9	12.3	<.01

* 12 df.

APPENDIX F

TABLE 23

t test of the mean difference in errors between final training trial and first retention trial for dynamic procedural sequences

<u>Dynamic Procedure</u>	<u>Group 10</u>			<u>Group 5</u>		
	<u>Mean Diff.</u>	<u>t*</u>	<u>Reliability of Diff.</u>	<u>Mean Diff.</u>	<u>t*</u>	<u>Reliability of Diff.</u>
Takeoff	0.9	2.7	.02>P>.01	1.2	3.1	<.01
Level-off	0.8	2.3	.05>P>.02	0.5	1.6	NS
Slow flight	0.8	2.2	.05>P>.02	1.1	1.6	NS
360° desc right turn	0	0	NS	0.2	0.9	NS
Normal cruise	0.8	2.1	NS	0.9	1.0	NS
Glide	0.2	0.7	NS	0.4	1.0	NS
Landing checkoff	1.2	2.5	.05>P>.02	0.5	0.8	NS
Final approach	0.5	2.1	NS	0.2	1.1	NS
All combined	5.2	4.1	<.01	4.9	2.7	.02>P>.01

*12 df

TABLE 24

t test of the mean difference in errors between final training trial and first retention trial for emergency procedural sequences

<u>Emergency Procedure</u>	<u>Group 10</u>			<u>Group 5</u>		
	<u>Mean Diff.</u>	<u>t*</u>	<u>Reliability of Diff.</u>	<u>Mean Diff.</u>	<u>t*</u>	<u>Reliability of Diff.</u>
Prop overspeed	2.2	2.6	.05>P>.02	3.0	3.9	<.01
Fuel warning	1.3	4.0	<.01	1.2	1.9	<.10
All combined	3.5	3.6	<.01	4.2	3.5	<.01

* 12 df.

APPENDIX G

VALUES ON EACH TRIAL FOR PERFORMANCE ON
FLIGHT PARAMETERS DURING EMERGENCIES AND FOR TIME
TO COMPLETE EMERGENCY PROCEDURAL SEQUENCES.

APPENDIX G

TABLE 25
Mean time (sec.) to complete emergency procedures

Emergency Procedures	Training Trials				Retention Trials									
	1	2	3	4	5	6	7	8	9	10	1	2	3	4
<u>Group 10</u>														
Prop Overspeed	96.9	82.9	70.4	79.6	76.8	68.8	58.9	60.6	65.0	56.1	80.5	56.6	52.3	53.8
Fuel Warning	105.3	74.5	78.5	75.7	69.3	61.9	68.4	65.0	58.0	61.5	57.2	60.5	58.8	51.5
Both Emergencies Combined	101.1	78.7	74.5	77.7	73.1	65.4	63.7	62.8	61.5	58.8	68.9	58.6	55.6	52.7
<u>Group 5</u>														
Prop Overspeed	123.6	113.7	75.4	83.3	95.9						84.3	73.6	68.9	67.5
Fuel Warning	104.8	101.4	100.2	90.4	78.7						69.8	82.9	78.2	65.2
Both Emergencies Combined	114.2	107.6	87.8	86.9	87.3						77.1	78.3	73.6	66.2

APPENDIX G

TABLE 26

Mean altitude (feet) lost during emergency procedures															
Procedure	Training Trials										Retention Trials				
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	
	Group 10														
Prop Overspeed	612	648	508	307	562	491	332	432	482	478	751	438	439	450	
Fuel Warning	983	476	563	462	365	396	468	468	362	516	382	453	463	452	
Both emergencies combined	798	562	536	385	464	444	400	450	422	497	567	446	451	451	
	Group 5														
Prop Overspeed	1017	1106	589	392	574						815	553	471	658	
Fuel Warning	1243	647	806	723	418						437	707	653	520	
Both emergencies combined	1130	877	698	558	496						626	630	562	589	

APPENDIX G

TABLE 27
 Mean minimum airspeed (MPH) during emergency procedures

Emergency Procedures	Training Trials						Retention Trials							
	1	2	3	4	5	6	7	8	9	10	1	2	3	4
<u>Group 10</u>														
Prop														
Overspeed	96.5	100.7	100.4	104.5	102.6	105.4	107.5	109.0	103.5	108.4	106.6	109.2	109.4	107.5
Fuel														
Warning	82.0	100.7	109.4	105.8	106.2	103.0	105.6	105.9	109.0	108.2	109.5	108.6	106.6	109.2
Both														
Emergencies														
Combined	89.3	100.7	104.9	105.2	104.4	104.2	106.6	107.5	106.3	108.3	108.1	108.9	108.0	108.4
<u>Group 5</u>														
Prop														
Overspeed	91.3	94.2	98.8	103.7	100.1						103.6	104.2	103.8	107.8
Fuel														
Warning	84.7	95.8	99.8	99.8	106.8						107.8	95.6	106.2	107.2
Both														
Emergencies														
Combined	88.0	95.0	99.3	101.8	103.5						105.7	99.9	105.0	107.5

APPENDIX H

**VALUES FOR THE FLIGHT PARAMETERS OF ALTITUDE,
AIRSPEED, AND BANK FOR EACH TRIAL FOR EACH
MANEUVER**

APPENDIX H

TABLE 28

Maneuvers	Training Trials										Retention Trials			
	1	2	3	4	5	6	7	8	9	10	1	2	3	4
Level off	138	105	93	94	57	40	58	28	31	26	46	44	27	27
Straight and level	48	45	26	28	23	20	21	23	17	16	25	19	19	17
Low visibility turn	138	108	81	59	56	77	44	29	64	29	31	36	25	20
Change to slow flight	98	90	143	86	69	55	38	25	40	30	69	49	30	36
Change to normal cruise	158	143	136	130	79	58	52	49	43	34	32	29	36	30
Landing Checklist	154	141	116	105	83	57	39	50	37	26	76	37	33	30
Procedure turn	143	89	37	51	51	47	38	42	29	38	55	36	25	24
1-min. leg	199	126	65	94	64	82	57	69	40	56	72	59	44	33
Procedure right turn	135	106	87	81	60	55	43	39	38	32	51	39	30	27
Grand Mean														
Level off	112	77	120	45	42						54	44	36	30
Straight and level	28	30	24	13	17						19	20	17	19
Low visibility turn	170	70	44	33	39						47	52	36	25
Change to slow flight	157	71	93	75	63						122	59	59	53
Change to normal cruise	142	81	88	66	80						70	61	49	42
Landing checklist	136	113	93	71	60						110	65	83	84
Procedure turn	120	92	74	53	42						46	51	41	31
1-min. leg	172	85	71	60	54						89	82	62	53
Procedure right turn														
Grand Mean	130	77	76	52	50						70	54	48	42

TABLE 29

Mean absolute airspeed error (MPH) for each maneuver for each trial

Maneuvers	Training Trials										Retention Trials			
	1	2	3	4	5	6	7	8	9	10	1	2	3	4
Takeoff and climb	8.6	6.4	5.5	4.8	4.1	3.1	3.2	2.4	3.0	2.7	3.4	3.3	2.8	2.5
180° right climb-	7.8	5.1	2.7	2.7	2.5	3.1	2.2	2.1	2.1	2.1	2.7	1.6	1.9	2.0
ing turn														
180° left climb-	5.0	4.3	2.4	3.4	2.4	2.0	1.9	1.8	3.4	1.5	3.0	1.4	1.7	1.2
ing turn	7.5	3.5	2.9	2.9	3.7	2.4	1.9	2.5	2.4	1.9	1.9	2.0	1.8	2.0
Straight climb	2.1	2.1	1.6	1.9	1.5	1.0	1.5	1.2	1.0	1.0	1.6	1.0	1.1	1.1
Straight and level														
360° desc right	10.2	6.5	7.2	6.4	4.5	4.2	4.8	4.3	4.4	4.0	5.9	3.8	3.7	4.7
turn														
Procedure turn	7.0	5.2	3.9	4.1	3.8	3.7	3.4	4.1	2.6	2.8	3.6	2.9	2.7	2.6
1-min. leg	6.0	5.4	5.3	5.1	4.4	3.4	3.0	2.8	2.8	2.0	3.0	2.8	2.2	2.3
Final approach														
Grand Mean	6.8	4.8	3.9	3.9	3.4	2.9	2.7	2.7	2.7	2.3	3.1	2.4	2.2	2.3
	Group 5													
Takeoff and climb	8.8	8.7	6.0	6.6	5.9						7.0	4.9	3.7	2.6
180° right climb-	6.0	5.7	4.3	2.6	3.8						10.5	9.3	5.8	2.9
ing turn														
180° left climb-	7.4	8.1	4.2	2.3	2.8						7.0	5.8	4.0	2.7
ing turn	4.6	2.7	2.6	2.4	3.0						6.7	4.9	3.4	1.6
Straight climb	2.1	1.8	1.9	1.3	1.2						1.4	1.3	1.2	1.4
Straight and level														
360° desc right	9.4	6.3	6.7	5.4	5.2						5.4	5.4	4.7	3.8
turn														
Procedure turn	5.6	4.9	4.7	3.9	3.8						4.4	5.3	3.6	2.5
1-min. leg	6.7	5.0	5.0	4.6	4.4						6.8	5.4	3.8	2.4
Final approach														
Grand Mean	6.3	5.4	4.4	3.6	3.8						6.2	5.3	3.8	2.5

APPENDIX H

TABLE 30

Maneuvers	Training Trials										Retention Trials			
	1	2	3	4	5	6	7	8	9	10	1	2	3	4
	Group 10													
180° right climb- ing turn	1.7	2.1	1.0	1.3	1.0	1.0	0.6	0.9	1.0	1.3	1.1	1.0	0.8	0.8
180° left climb- ing turn	1.9	2.1	1.6	1.4	0.9	1.3	1.1	1.2	0.8	0.8	1.1	0.9	1.0	0.6
Low visibility turn	2.3	1.6	1.8	2.0	1.7	1.7	1.5	1.9	1.5	1.4	2.8	1.7	2.0	1.7
360° descending right turn	3.7	1.8	1.9	1.7	1.3	1.2	1.3	1.4	1.1	1.2	1.1	1.3	0.8	1.1
Procedure right turn	2.3	1.7	1.3	1.1	0.9	0.7	0.7	1.1	1.1	0.9	1.1	1.0	0.6	0.7
Grand Mean	2.4	1.9	1.5	1.5	1.2	1.2	1.0	1.3	1.1	1.1	1.4	1.2	1.0	1.0
	Group 5													
180° right climb- ing turn	1.8	2.1	1.9	1.1	1.1						2.4	1.1	1.0	1.0
180° left climb- ing turn	2.8	1.7	1.3	1.4	1.7						1.4	1.4	1.0	1.0
Low visibility turn	2.5	2.4	1.9	2.1	1.9						3.3	2.1	1.9	2.0
360° descending right turn	2.8	2.3	2.2	1.7	1.6						1.7	1.6	1.0	1.4
Procedure right turn	1.9	2.0	1.4	1.0	1.6						1.2	1.2	1.2	1.1
Grand Mean	2.4	2.1	1.7	1.5	1.6						2.0	1.5	1.2	1.3

APPENDIX I

**VALUES ON INDIVIDUAL TRIALS FOR ERROR ON THE
INITIATION OR COMPLETION OF A MANEUVER**

APPENDIX I

TABLE 31

Mean absolute error (feet) in leveling off at a new prescribed altitude value. The tabled mean value is for the four maneuvers involving altitude change

Group	Training Trials							Retention Trials						
	1	2	3	4	5	6	7	8	9	10	1	2	3	4
10	142	66	73	79	37	29	34	32	18	15	19	30	20	14
5	170	142	87	50	37						80	60	102	16

TABLE 32

Mean absolute error (degrees) for heading at completion of a turn. The tabled mean value is for the seven maneuvers involving heading change

Group	Training Trials							Retention Trials						
	1	2	3	4	5	6	7	8	9	10	1	2	3	4
10	9.4	6.3	4.9	4.5	3.0	3.5	2.6	3.3	2.4	2.8	3.8	2.6	2.5	2.2
5	12.2	5.6	5.9	3.5	3.4						8.9	5.6	4.1	3.0

TABLE 33

Total number of directional bank errors on initiating or completing a turn. Fourteen errors are possible on each trial and, with 13 subjects in a group, the total possible number per trial is 182

Group	Training Trials							Retention trials						
	1	2	3	4	5	6	7	8	9	10	1	2	3	4
10	20	11	10	9	3	4	3	3	2	2	4	5	2	2
5	20	12	6	5	3						9	3	7	4

APPENDIX J

FOR EACH GROUP, t TEST FOR RELATED MEASURES OF
THE MEAN DIFFERENCE BETWEEN FINAL TRAINING TRIAL
AND FIRST RETENTION TRIAL FOR THE ABSOLUTE ERROR
IN ALTITUDE, BANK, AND AIRSPEED ON THE INDIVIDUAL
MANEUVERS OF THE FLIGHT

APPENDIX J

TABLE 34

t test of the mean difference between final training trial and first retention trial for absolute error in airspeed

Maneuver	Group 10			Group 5		
	Mean Diff.	<u>t</u> *	Reliability of Diff.	Mean Diff.	<u>t</u> *	Reliability of Diff.
Takeoff and climb	0.6	1.5	NS	1.1	0.5	NS
180° right climbing turn	0.6	1.0	NS	6.7	2.5	.05>P>.02
180° left climbing turn	1.5	1.8	NS	4.2	2.1	NS
Standard climb	-0.5	-0.1	NS	3.7	1.5	NS
Straight and level	0.7	1.8	NS	0.1	0.6	NS
360° descending right turn	1.9	1.5	NS	0.1	0.1	NS
One-min. leg on procedural turn	0.8	1.3	NS	0.5	0.7	NS
Final approach	1.0	2.8	NS	2.3	1.6	NS
All combined	0.9	2.7	.02>P>.01	2.3	2.4	.05>P>.02

*12 df.

APPENDIX J

TABLE 35

t test of the mean difference between final training trial and first retention trial for absolute error in altitude

Maneuver	Group 10			Group 5		
	Mean Diff.	<u>t</u> *	Reliability of Diff.	Mean Diff.	<u>t</u> *	Reliability of Diff.
Level-off	21.6	2.6	.05>P>.02	12.7	1.1	NS
Straight and level	9.5	2.1	NS	1.9	0.5	NS
Low visibility turn	2.0	0.3	NS	7.8	0.7	NS
Slow flight	38.8	2.1	NS	58.5	1.6	NS
Normal cruise	-1.3	0.2	NS	-10.7	0.4	NS
Landing check	50.1	2.4	.05>P>.02	49.5	2.5	.05>P>.02
One-min. leg on procedural turn	17.3	1.0	NS	4.1	0.3	NS
180° procedural right turn	19.5	0.7	NS	38.5	1.5	NS
All combined	19.7	2.4	.05>P>.02	19.3	4.1	<.01

*12 df.

APPENDIX J

TABLE 36

t test of the mean difference between final training trial and first retention trial for absolute error in bank

Maneuver	Group 10			Group 5		
	Mean Diff.	<u>t</u> *	Reliability of Diff.	Mean Diff.	<u>t</u> *	Reliability of Diff.
180° right climbing turn	-0.2	0.9	NS	1.3	2.8	.02 > P > .01
180° left climbing turn	0.3	1.3	NS	-0.4	1.2	NS
Low visibility turn	1.3	1.5	NS	1.4	1.8	NS
360° descending right turn	-0.1	0.7	NS	0.0	0.1	NS
180° procedural right turn	0.2	1.2	NS	-0.5	1.1	NS
All combined	0.3	1.6	NS	0.4	3.0	.02 > P > .01

*12 df.