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The Forgetting of Instrument Flying Skills

ROBERT F. MENGELKOCH, *Bunker-Ramo Corporation, Dayton, Ohio,* JACK A. ADAMS, *University of Illinois, Champaign, Illinois, and* CHARLES A. GAINER, *Bunker-Ramo Corporation, Canoga Park, California.*

A laboratory study of forgetting was conducted, using an aircraft simulator as the research device. Two groups of subjects were used, with one group receiving twice the amount of original training as the other. The retention interval was four months for both groups. The principal result was that discrete procedural response sequences had statistically and practically significant loss over the retention interval, but proficiency in controlling flight parameters (tracking) and statistically significant losses in only some instances and never in operationally significant amounts.

A considerable portion of military flying is subsumed under "proficiency flying" and it is predicated on the belief that forgetting of flying skills occurs during periods of non-practice and that periodic flying is necessary to maintain an acceptable level of proficiency. This belief cannot be questioned because it is secured in the laboratory data of experimental psychology and is well-grounded in the practical experiences of pilots. Yet, neither of these sources of information can 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. If these data were available, amounts and types of flying could be specified to maintain proficiency in the most economical manner. Also, the types of training devices for a particular class of aircraft, as well as their use, could be specified for the restoration of proficiency. Currently the contributions of flying itself, classroom training, general instrument trainers, cockpit procedures trainers, and simulators to the maintenance of flying proficiency are only dimly known. It is this need for objective data on the forgetting of flying skills that motivated the study reported here.

METHOD

Experimental Design

The experimental design used two groups of subjects and an aircraft simulator as the research device. Following a four-hour academic training program and one familiarization trial in the simulator, 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 simulator, respectively. A retention interval of four months followed 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-min. mission of maneuvers and procedures from starting the engine and takeoff to landing and shutdown of the engine.

Research Equipment

The experimental apparatus used in this study was the Link 1-CA-2 simulator for the SNJ aircraft. The simulator was used in its standard configuration except for three modifications:

1. The rudder control was disconnected so that the turning rate 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 simulator 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 a desired rate of turn, the controls then 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 simulator 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 redesigned 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.

3. For the scoring of performance, the simulator 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 station. All flight and engine instruments of the cockpit 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, 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 simulator had been used in a pseudocontact configuration where the subject could view the cyclorama surrounding the simulator 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 the amount of forgetting may be a function of the cues involved, it was considered an important experimental control to limit the cues to the cockpit only. Therefore, the canopy of the simulator was covered with white paper so that with the canopy closed it was impossible to see out of it. The white paper allowed some illumination from overhead lights but two directional lights also were placed in the cockpit to insure adequate illumination of the instrument panel. A two-way intercom system was employed for communication between experimenter and subject.

Flight Training Methods.

Academic training. The subjects of this experiment were naive to flying, and it was necessary to start them with 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 simulator 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 too long to begin in the simulator and the forgetting of material presented in academic training would have been adversely reflected in their performance in the simulator.

The curriculum of the first academic session included: (1) A brief introductory statement on the nature of the experiment. (2) A film 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 by the experimenter to present the instrument readings for various flight conditions. (4) A film 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 three parts: (1) Acquaintance with the procedural sequences to be learned. There were 12 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 (Dougherty, Houston, and Nicklas, 1957) where the mock-up was found to benefit subsequent performance on procedures in an aircraft. (3) Written examinations on the procedures checklists and on flight conditions represented by various values set in the panel array of flight instruments. After the subjects had responded the correct answers were given and discussed.

Familiarization trial. Preliminary experimentation indicated that it was necessary to give a subject a familiarization period in the simulator before the scored training trials were begun. The flying task is of such complexity for a naive subject that the grossness of his errors on the very first time in the simulator precluded meaningful response measurement. After one trial the subject was sufficiently acquainted with the cockpit layout and techniques of simulator 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. This was done with the subject seated in the cockpit and the experimenter standing alongside the simulator. The subject was then put under the hood for the remainder of the trial and instruction proceeded over the intercom system. The familiarization period was identical in format to the criterion 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. The other card had throttle setting, RPM, fuel mixture, landing gear position, flaps position, and airspeed for representative flight configurations.

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 reproduced in the simulator. The sequence of the mission was: cockpit check, engine starting procedure, engine run-up check, takeoff checklist, actual takeoff, 180° left climbing turn, 180° right climbing turn, level off at 5,000 ft., straight and level leg, change to slow flight, 360° descending right turn (2,000 ft. loss of altitude), change to normal cruise, glide to 1,000 ft., landing check-off 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. The flight task is shown in Figure 1.

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 beside the simulator. All other maneuvers were performed with the canopy closed and were scored from the repeater console. The flight task was designed to take 50 min., 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.

Performance Recording

Flight parameters. Proficiency in flight control is revealed in the extent to which basic flight instruments are kept aligned with a value defined as ideal for a maneuver. The primary flight parameters recorded were altitude, airspeed, bank, and heading, and each was scored in terms of error deviation from the index of desired performance for the maneuver each time the experimenter observed a signal light on his console which flashed at 10-sec. intervals. This method gave several measures for each parameter on a maneuver, which increases the reliability of measurement.

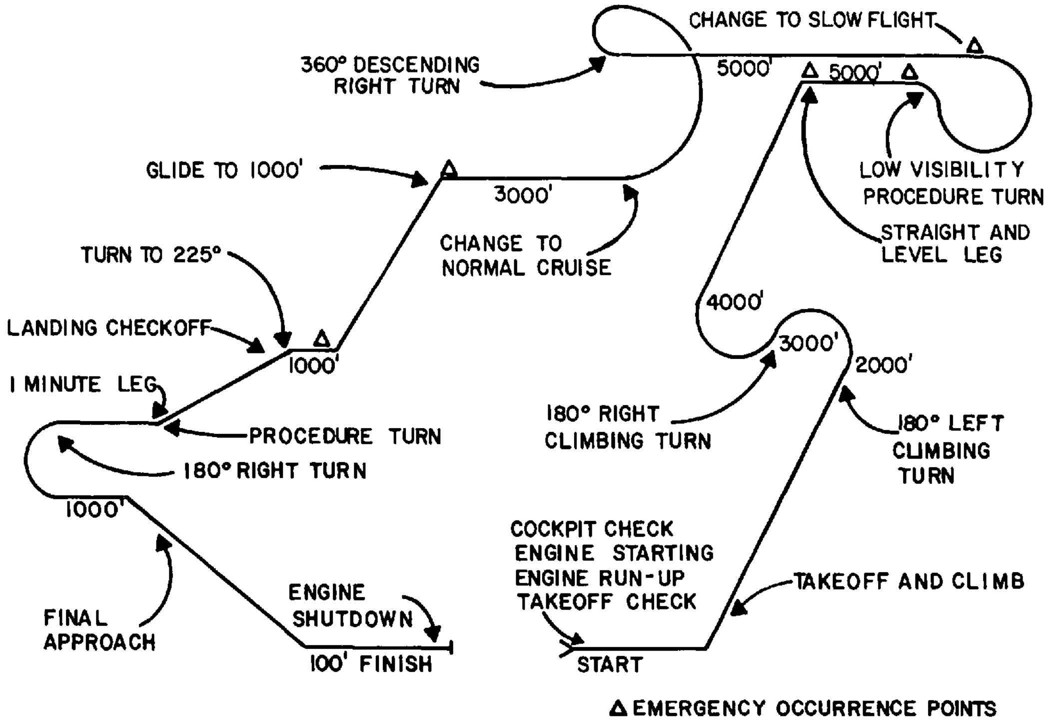

Figure 1. Mission sequence. This mission was used on every trial.

The heading measure ordinarily was not used because heading values were insensitive to small changes in bank. This was a result of inadequacies in the computational equipment of the simulator. Adjustment of the simulator to provide proper relationships between degree of bank and airspeed in executing a standard rate turn resulted in an insensitivity of the heading indicator for small changes in bank. 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. This measure was found to be meaningful and was included in the analysis.

Procedures. There were 125 discrete procedural items on a trial which were scored on an error-no-error basis. An error in procedures was scored if the item was either omitted or performed wrong, or occurred out of place in the sequence (providing that position in the sequence happened to be important for the item).

Subjects

Thirty-three University of Illinois ROTC male undergraduate students participated in the study. 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. They were paid for their participation.

Four subjects were used in preexperimental 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. Although the training trials would have been facilitated if subjects with some flying experience, such as private pilots, had been used, the decision was to use naive subjects. The determining factor for this decision was the problem of controlling 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 (Sutter, Townsend and Ornstein, 1954) has shown that light plane flying has a positive transfer effect to the T-6 (about the same as the SNJ) aircraft, it would be reasonable to expect that pleasure flying in the retention interval might transfer positively to the SNJ simulator, thereby biasing recall. To avoid this difficulty, the training of naive subjects was undertaken.

Experimenters

Two experimenters were used. Both were ex-military pilots.

RESULTS

Method of Data Analysis

Flight parameters. At each 10-sec. interval throughout a maneuver the error deviation from an index of desired performance was recorded for each relevant flight parameter, and the basic measure for each subject in controlling a flight parameter on a maneuver was the mean absolute error deviation of the measures taken. These means for a subject on a parameter were averaged over all maneuvers to obtain an overall measure of his proficiency on a trial.

Procedures. The score for a subject in procedures was number of items correct.

Statistical analysis. All statistical tests were performed on raw scores. The coefficient of risk was .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 was significant, indicating that the two groups were equivalent in average ability.

General Observations on Training Methods

Considering the complexity of the flying task assigned to the subjects, and considering that subjects were naive with respect to flying, a problem was to use 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 photographic cockpit mock-up found effective in previous research (Dougherty, Houston and Nicklas, 1957) for the teaching of procedures, a familiarization trial in the simulator 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 methods were effective. Group 10 was intended to be a high-proficency 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 simulator. To illustrate, Group 10 on Training Trial 10 missed only 3.9% of the 125 procedural items, had 1.1° of mean error in bank, 32 ft. 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 simulator 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 but intermediate level of proficiency.

Retention of Procedures

Learning of procedures. Figure 2 shows the original learning and retention curves for the 125 procedures, with percent 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. The values on training Trial 1 indicate that about half of the procedural responses were learned in academic training and on the familiarization trial.

Retention loss. Group 10 had a 16.5% loss over the four-month interval, and Group 5 had a 20.1% loss. The t test established both of these losses as significant ($p<.01$). A test of the difference between the two loss values failed significance, indicating that amount of original training did not differentially affect the amount forgotten.

Trials to relearn. Group 10 required more trials to relearn procedures than Group 5. Group 5 equaled or exceeded its performance level of the final training trial by the fourth (and final) relearning trial, but Group 10 failed to acquire its original proficiency by the fourth relearning trial.

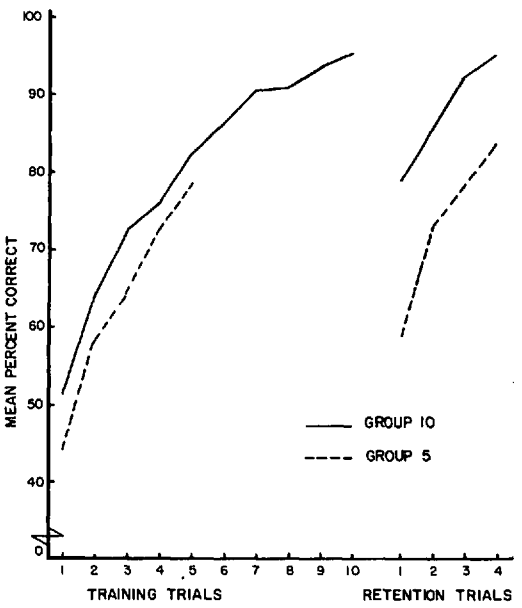

Figure 2. Performance on procedures.

Retention of Flight Parameters

Learning to control flight parameters. Figures 3–7 present the performance curves of the two groups for the five flight parameters. As with procedures, all measures of flight

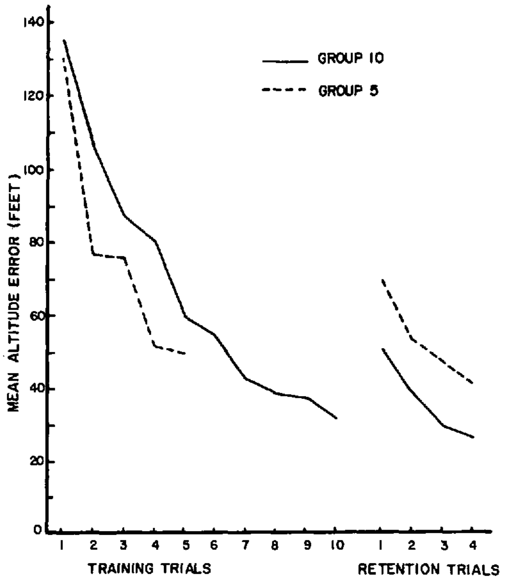

Figure 3. Accuracy in controlling altitude, averaged over all maneuvers.

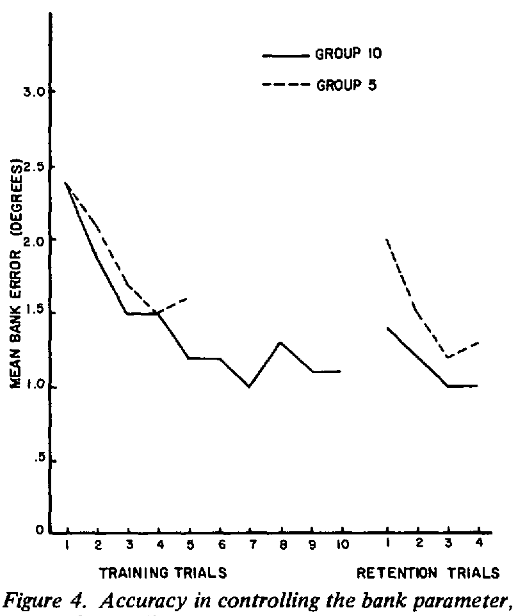

Figure 4. Accuracy in controlling the bank parameter, averaged over all maneuvers.

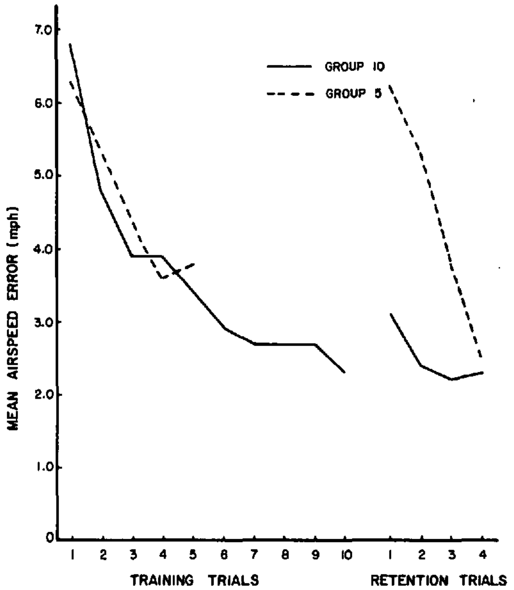

Figure 5. Accuracy in controlling airspeed, averaged over all maneuvers.

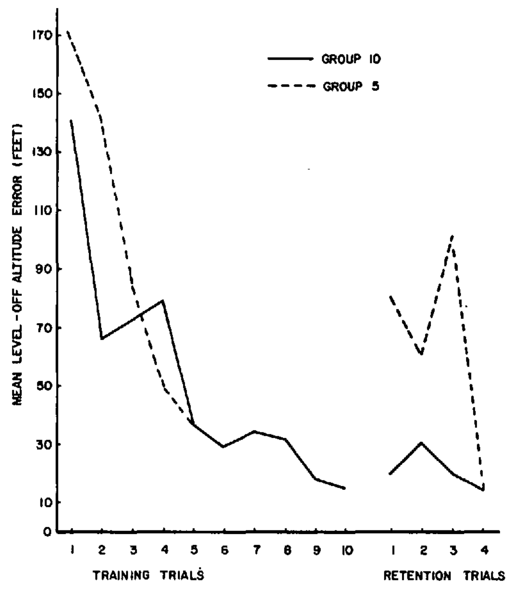

Figure 6. Accuracy in leveling off at the correct altitude, averaged over all maneuvers.

parameters show negatively accelerated learning over training trials.

Retention loss. Table 1 gives the results of a t test for the retention loss of each group on each flight parameter. Statistical significance

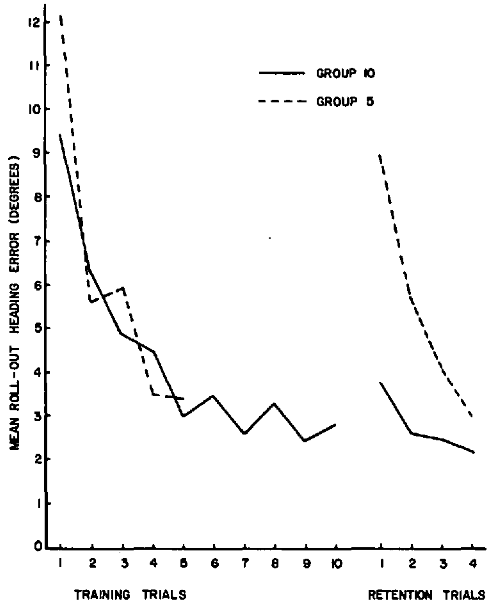

Figure 7. Accuracy in achieving correct heading at the completion of a turn, averaged over all maneuvers.

for flight parameters was obtained less frequently than for procedures. 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 2. None is statistically significant.

Trials to relearn. The number of retention trials taken to relearn to the performance level attained on the final training trial is given in Table 3. There was a slight tendency for Group 5 to take longer than Group 10 to relearn.

DISCUSSION

The main findings of this study are:

1. Discrete procedural responses are more susceptible to forgetting than flight control responses. For both groups, procedural responses had a statistically significant retention loss over the retention interval. Of the five flight parameters, only altitude and airspeed had a significant loss over the retention interval for both groups. The loss for the bank parameter was significant for Group 5 only, and the

TABLE 1

t Test of Mean Difference between Final Training Trial and First Retention Trial for Each Flight Parameter

	Group 10			Group 5		
Flight Parameter	*Mean Difference*	t*	*Reliability of Difference*	*Mean Difference*	t*	*Reliability of Difference*
Altitude (ft.)	19.7	2.4	$.05>p>.02$	19.3	4.1	$p<.01$
Bank (°)	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 (ft.)	6.2	1.8	NS	44.1	2.0	NS
Roll-out on new heading (°)	1.0	1.4	NS	5.5	1.9	NS

* 12 *df*

TABLE 2

t Test of Mean Difference in Retention Loss between Group 10 and Group 5 for Each Flight Parameter

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

* 24 *df*

TABLE 3

Trials to Relearn*

Flight Parameter	*Group 10*	*Group 5*
Altitude	3	3
Bank	3	2
Airspeed	3	3
Level-off at altitude	4	4
Roll-out on new heading	2	4
Mean	3.0	3.2

* For each flight parameter, the tabulated value is the number of the retention trial where the mean performance level on the final training trial was first equaled or exceeded.

other two parameters did not have a significant loss for either group.

2. The amount of initial training did not influence the amount of the retention loss. A corollary of this finding is that Group 10 with the higher level of initial training 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.

3. The number of trials taken to relearn procedures is a positive function of the amount of initial training, and is less than that taken to train originally. For flight control measures, time to relearn differed little as a function of amount of original training.

The finding 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 is level of learning; there is no way of operationally defining the statement that the two different classes of responses have equal levels of learning (Adams, 1967, Chapter 8). Thus, we are not justified in implying the generalization that procedural responses are intrinsically forgotten more readily than tracking responses. Our findings have importance within the practical context of aviation, however.

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. Group 10 had a mean loss of only 19.7 ft. of altitude, and Group 5 had a loss of 19.3 ft. 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. Certainly the absolute amounts of these losses cannot be construed as operationally important. However the loss of 16.5% of all procedures by Group 10 and 20.1% 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 aircraft 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. This is fortunate from the standpoint of economy because procedures are 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 were learned prior to the first training trial, indicating that four hours of academic training and one familiarization trial were potent training techniques. Obviously a great deal of training can be accomplished with simple classroom training aids. Research has shown that a full-scale photographic mock-up of the cockpit can be effective (Dougherty, Houston, and Nicklas, 1957). 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 can be useful. 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 a simulator (configuration of a specific aircraft). A simulator is the best all-round training device because all classes of procedures can be practiced with it, as well as aircraft flight control. Simulators, however, are complex devices that have high initial and maintaining costs. In lieu of a simulator, training benefits for procedures can be obtained from classroom training, a photographic mock-up of the cockpit, or a cockpit procedures trainer.

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