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Technical Report: NAVTRADEVCEN 297-2

THE CONTRIBUTION OF PART TASK TRAINING TO THE RELEARNING OF A FLIGHT MANEUVER

U.S. NAVAL TRAINING DEVICE CENTER
PORT WASHINGTON, L.I., NEW YORK

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THE CONTRIBUTION OF PART-TASK TRAINING TO THE RELEARNING OF A FLIGHT MANEUVER

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ABSTRACT

The purpose of this study was to determine the contribution of part-task training to the relearning of a whole-task. An experiment was performed using subjects who had learned the whole-task (a simulated bomb-toss maneuver) during participation in the previous study, "Part- Versus Whole-Task Learning of a Flight Maneuver", TR NAVTRADEVCEN 297-1 but had lost proficiency as a result of a ten-month interval of non-practice. Half the subjects obtained part-task refresher training prior to whole-task training; the other half obtained whole-task training only. Results revealed that while part-task training could not completely substitute for whole-task training, it substantially reduced the number of whole-task trials needed.

FOREWORD

Introduction and Purpose

A previous study in this series--"Part-Versus Whole-Task Learning of a Flight Maneuver" (TR NAVTRADEVCEN 297-1)--revealed that part-task training can contribute to learning a whole-task, but that some whole-task learning is still necessary. Specifically, the initial learning of a simulated bomb-toss maneuver which entailed concurrent performance of flight control and procedural tasks benefited considerably from training in the procedures trainer (part-task), but still required a nominal amount of concurrent practice in the OFT (whole-task) before it was fully learned. The question then emerged as to whether part-task training would aid also the relearning of a forgotten whole-task. The purpose of the present study therefore was to identify and measure the contribution that part-task training in procedures only would make to the relearning of a maneuver consisting of time-shared procedures and flight control tasks.

Method

Twenty subjects from the "learning study" (TR NAVTRADEVCEN 297-1) returned to the laboratory after an interval of ten months during which their proficiency in the bomb-toss maneuver had almost completely disappeared. Half the subjects were given ten refresher training trials in the cockpit procedures trainer, while the other half served as control group, i.e., received no practice. Then, each of the twenty subjects was asked to perform ten whole-task trials in the OFT.

Results

The findings revealed that practice in the part-task trainer was of considerable help in regaining proficiency in the whole-task. The group which had part-task practice relearned the maneuver by the third whole-task trial. The control group - which did not have part-task practice - did not relearn it until the fifth whole-task trial.

Implications

Part-task training is beneficial for relearning the whole-task just as it is of value for the original learning. That it can substitute for whole-task training--although not on a trial-by-trial basis--is of great practical importance because of the much higher cost of whole-task training practice.

It should be emphasized that the hypothetical bomb-toss maneuver used in this study was selected because it involved very close interaction between procedural and flight control tasks. This maximized time-sharing

and minimized the potential contribution of part-task training. The fact that part-task training was so valuable even under these circumstances permits us to anticipate as great and even greater payoffs for the relearning of other types of whole-tasks.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

BRIEF OF STUDY

A cockpit procedures trainer (CPT) is a static training device for the training of aircraft procedures and lacks the simulation of aerodynamic flight control that characterizes whole-task flight simulators like the Navy Operational Flight Trainers (OFT). An earlier study demonstrated that procedures which normally had to be time-shared with flight control responses did not fully transfer to the dynamic whole flight task when they were originally learned in a CPT. Maximum proficiency in time-shared procedures could be gained only by additional practice in the total flight task. This finding was taken as support for the hypothesis of a learned interaction between procedural and flight control responses that can be acquired only when the two response classes are practiced together in their proper time-shared relationship. A CPT was shown to be a useful training device but it does have this disadvantage for a particular class of procedural sequences.

While CPTs have a shortcoming for original learning, it may be that they can be almost completely effective for the relearning of procedures forgotten over a period of non-practice and, if true, this hypothesis could have extensive implications for flight training. To check this, 20 of the 30 subjects in the original CPT experiment were returned to the laboratory for a retention test after an interval of 10 months. Half of the subjects were given refresher practice in a CPT and the other half served as control subjects. As before, an SNJ OFT was used to fly a hypothetical toss-bomb maneuver. The data revealed that the forgetting of procedures was almost complete over 10 months, with only about five per cent correct. The CPT practice restored some of the lost proficiency in procedures but it was not completely effective. Two additional whole-task trials were required to raise proficiency to the level held 10 months earlier. It was concluded that time-sharing is a variable in recall and relearning, just as it is in original learning. Another restriction is defined for CPTs.

Because whole-task trials are required which cannot be obtained in a CPT nor, in the case of emergency procedures, in the actual aircraft, a well-designed OFT appears to be the best single training device for the practice of time-shared procedures. However, the distinct contribution of the CPT to a substantial portion of this learning should not be overlooked or minimized.

DETAILS OF THE STUDY

INTRODUCTION

Most flight trainers today are whole-task aircraft simulators (e.g., OFTs) by providing practice in procedures and flight control sequences associated with the entire mission, or at least significant portions of it. Flight simulators are costly to build and use, but they still have training costs far less than aircraft and are justified by their capabilities for training pilots in the many different kinds of complex skills required to fly modern aircraft. Simulators also have the well-known advantage of teaching responses, such as certain emergency procedures, which cannot be taught in the air for safety reasons. An independence of weather is another positive feature of simulators in a training program. Regardless of these undeniable merits of whole-task simulators, their cost and complexities have caused simulator designers and users to explore the possibilities of much simpler training devices for teaching critical classes of flying skills (Adams, 1957; Adams, Mengelkoch, and Gainer, 1958; Bray, 1954; DiVall, 1957; Dougherty, Houston, and Nicklas, 1957; Middleton, Allred, and Townsend, 1955; Muckler, Nygaard, O'Kelly, and Williams, 1959; Schohan, 1958; Wolfle and Garman, no date). This interest has led to the development of part-task trainers which deliberately avoid the complexities of whole-task simulation by including only a portion of the task for training specific, critical skills.

Part-task simulators are defensible on grounds other than their relative simplicity and low cost. In transitioning to a new aircraft, it has been argued that the pilot in training need focus only on learning new skills because considerable reliance can be placed on the high transfer from previous flying experience for other response classes. For example, we might expect a good degree of similarity in aerodynamic flight control responses from one aircraft to another and so

there would be little need to use a training device with expensive aerodynamic simulation for pilot trainees who have had extensive flying experience. However, one aircraft differs most markedly from another in normal and emergency procedures and it is these new responses that deserve primary emphasis in training devices. Another justification for part-task simulators is that they can be used for original or refresher training in skills which do not receive enough initial practice or refresher training to maintain proficiency at the required level. Emergency procedures, for example, may almost never be used by a pilot, and yet his proficiency in them must be maximum at all times if he is to be safe and proficient. A part-task trainer which focuses just on procedures training could be used both for the initial training and refresher training in these critical response sequences.

On justifications such as these, this latter type of part-task simulator has become increasingly popular and is known as a cockpit procedures trainer (CPT). It is commonly used as a transition training device for a pilot to learn the cockpit location of instruments and controls on the new aircraft he is to fly, and particularly to allow him practice of the many sequences of discrete procedural responses of his new aircraft. The principal difference between a CPT and a whole-task simulator is that the CPT has no aerodynamic simulation whatsoever, and this complete absence of the analog simulation components for continuous solution of aerodynamic equations is the major factor in their relatively low cost and simplicity. Some of the cockpit elements are operable, such as emergency warning lights, but cockpit elements which are ordinarily dynamic are static in a CPT. When the instructor presents the cockpit cue configuration for the procedural sequence, the trainee responds and tell-tale indicators on the instructor's panel provide the basis for informative feedback. In some instances the instructor's verbal statement provides the cue framework for the pilot's procedural responding ("There is a

muffled explosion in the tailpipe and smoke is entering the cockpit").

Cockpit procedures trainers have had the criticism that inflight procedures learned in this manner will have an attenuated amount of transfer to inflight performance because the absence of aerodynamic simulation in CPTs has not allowed for the learning of time-sharing. Time-sharing, as a descriptive term for complex behavior such as flying, implies that in addition to the learning of specific responses and sequences, there is the added learning requirement associated with the correct distribution and patterning of two or more concurrent response classes in time. Sometimes time-sharing requires the two response classes to be performed simultaneously, although in other cases it could be a synchronized interlacing of the two response classes over time. Whatever the nature of time-sharing, the hypothesis contends that time-sharing imposes a special learning requirement on the pilot. A report by Middleton, et al., (1955) on evaluation of the T-33A CPT was perhaps the first to suggest the ad hoc hypothesis that CPTs may contain an intrinsic deficiency because the complete absence of aerodynamic simulation does not allow the learning of time-sharing between procedures and flight control which have to be performed together. The hypothesis holds that even though in-flight procedures have been learned perfectly in a CPT, transfer to the aircraft will be less than 100% because the critical time-sharing component of the total responding is absent. Practice in a CPT must be followed by some whole-task practice, either in the aircraft or an OFT, so the time-sharing can be learned and proficiency maximized. This general line of criticism also has been made by DiVall (1957), Schohan (1958), and Muckler, et al., (1959). A study by Dougherty, et al., (1957) tested the hypothesis that transfer to inflight performance of procedures in an SNJ aircraft could benefit from a one-dimensional tracking task in a CPT which the pilot would have to use continuously while practicing procedures. The hypothesis was not sustained by the findings. The performance of the time-sharing group did not differ significantly from groups which had no time-sharing.

A recent University of Illinois experiment undertook a thorough testing of the time-sharing hypothesis (Adams, Hufford, and Dunlop, 1960). An understanding of this issue is not only important for understanding the limitations of CPTs but also for any other part-task trainer. The SNJ OFT was used and the unit of study was a hypothetical toss-bomb maneuver that required the concurrent performance of ten procedural items and continuous flight control. A Control Group repeatedly practiced the whole maneuver. An Experimental Group, however, had separate learning of flight control and procedural responses. The procedures were learned in a static version of the OFT, which had properties quite similar to a CPT. In a final criterion session the Experimental Group was shifted to the whole task and required to perform the complete maneuver, just as the Control Group. Prior to the criterion session both groups had the same amount of practice in flight control and procedures. If the time-sharing hypothesis has validity, we would expect the Experimental Group performance to be below that of the Control Group in the criterion session because they always practiced the two major response classes separately and had no opportunity to learn time-sharing. The results supported the hypothesis. On the initial trial of the criterion session the performance of the Experimental Group in procedures was significantly below the Control Group. The experiment defined certain limitations for CPTs and indicated that, when procedures must be time-shared with flight control, original learning of the procedures should be followed by some integrated whole-task practice, either in an OFT or the aircraft itself, to allow for the learning of time-sharing.

This University of Illinois study in support of the time-sharing hypothesis emphasized that the findings apply only to the original learning of procedures. Although lacking empirical verification, it is plausible that CPTs can be almost completely effective for the maintenance of proficiency of experienced flying personnel, even though they have limitations for original learning. The learning of time-sharing may be a limiting consideration for CPTs only when the

procedures are first learned, but once having been acquired, the reinstatement of proficiency in procedures forgotten during a period of non-practice may be effectively accomplished with practice on a CPT. We do not know enough about the behavioral nature of time-sharing to hypothesize why this might be true, but it is an empirical possibility with extensive practical implications for flight training and it is deserving of experimental testing. Procedural responses are more readily forgotten than flight control responses (Adams et al., 1958; Mengelkoch, Adams, and Gainer, 1958) and it is important to examine methods and devices, particularly relatively simple ones, that can be used to reinstate this labile response class that is becoming increasingly important as more and more flight control sequences are becoming automatic. The experimental issue is the effectiveness of a CPT in reinstating forgotten procedures. As with original learning, we may find that time-sharing is important for the relearning of procedures and CPT practice can do only part of the job, with some integrative whole-task practice necessary to maximize the pilot's proficiency. The experiment to be reported here is an investigation of CPTs and the role of time-sharing in the reinstatement of proficiency in procedures forgotten over a period of 10 months.

EXPERIMENTAL METHOD

Experimental Design

The purpose of the experiment was to determine the efficacy of a CPT in relearning in-flight aircraft procedures after a retention interval of 10 months. Twenty private pilot subjects who had participated in the initial experiment on the use of a CPT in original learning of procedures (Adams et al., 1960) were located and asked to return for an additional practice session. Ten of the subjects were from the Experimental Group and had used a CPT as part of the training schedule in the original learning of procedures. The other 10 subjects were

members of the Control Group and had had whole-task practice throughout their original training. The same hypothetical toss-bomb maneuver was used as before and required both flight control and procedural responses to be time-shared in an SNJ OFT. The Control Group returned to flying the complete maneuver and continued with whole-task practice just as they had done 10 months earlier. The Experimental Group, however, first relearned the procedural sequence in a static version of the SNJ OFT which was very similar to a CPT. Following CPT practice, the Experimental Group shifted to whole-task practice of the complete maneuver in the dynamic OFT, just as the Control Group. If the CPT is completely effective for the reinstatement of proficiency in procedures lost as a result of forgetting processes, we can expect the initial trial of whole-task practice for the Experimental Group to achieve the performance level held at the start of the 10 months' retention interval. The Control Group provides a baseline comparison in terms of response reacquisition within the context of the whole-task.

Research Equipment

Trainer characteristics. The experimental apparatus was the SNJ OFT (Link 1-CA-2). Another SNJ OFT of the same model, but newer and recently overhauled, was used in place of the original trainer to provide greater equipment reliability during the experiment. The trainer was pre-flighted each day and calibrated to meet the same performance criteria required of the equipment in the first experiment. The entire instrument panel and armament control panel were removed from the original trainer and placed in the current device to insure comparability of the display and basic controls.

The trainer was not used in its basic SNJ configuration. In addition to being modified for higher speeds, the rudder control was disconnected such that the control of turning rate was entirely by the degree of bank established with aileron stick movement. The use of the rudder in a turn is a low fidelity aspect of the trainer because

it requires a constant input throughout the turn, which is in contrast to the SNJ aircraft where the appropriate input to aileron and rudder can be made and then neutralized, with the aircraft continuing through a coordinated turn until opposite inputs are initiated. This modification of the trainer gave it flight characteristics similar to a jet aircraft where the rudder is almost never used in airwork.

The canopy of the trainer was covered with white translucent paper, allowing some illumination from overhead lights to enter the cockpit. Two directional lights inside the cockpit were also used to insure full illumination of the instrument panel. A two-way intercom system was employed for communications between the experimenter and subject.

Cockpit instrumentation. The cockpit instrument panel mainly had only those flight instruments necessary for the bombing maneuver. In the center of the instrument panel was the attitude gyro. To the right and level with the attitude gyro was the airspeed indicator. Although the subject was not required to monitor airspeed and maintain any specific values during the maneuver, it was reasoned that any pilot would feel more comfortable with constant knowledge of this important flight parameter. Further, it was felt that knowledge of the relatively high airspeeds attained in the maneuver would give the subject some awareness of the rate of occurrence of events. To the left of the attitude gyro was the altimeter and to its left an eight-day time clock. Immediately below the altimeter was the vertical speed indicator. Directly above the attitude gyro was the slave gyro or directional indicator, and to the left of the slave gyro was the turn and slip indicator. All other instruments were covered with black paper, except two engine indicators at the far right hand side of the panel which did not concern the subject.

A single, red warning light was mounted on the middle left-hand side of the instrument panel at approximately eye level. This light was labeled "Toss Alert" and was illuminated by the experimenter as a cue for an item of the procedural sequence.

An 8 x 12-inch rectangular black panel, called the Armament Panel, was mounted on the lower left-hand side of the instrument panel. The panel had nine two-position toggle switches labeled as shown in Figure 1. The Armament Panel provided all the basic controls (with the exception of one verbal response) for the procedural responses of the flight task.

√ Timer	√ Temp N	√ Pressure
√ Fuse	√ Release	√ Detonator
√ Safety	√ Voltage	√ Critical

Fig. 1. Armament panel showing procedural switches.

Method of performance measurement. The trainer was wired so that the data of all necessary flight instruments and procedural controls appeared on a repeater console at the experimenter's desk where an objective record of a subject's performance was taken. All flight and engine instruments were repeated directly with the exception of the attitude gyro, 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 switch of the Armament Panel had a red light on the console which informed the experimenter at all times when the switch was ON.

Flight Training Methods

Description of the maneuver. The toss-bomb maneuver is diagrammed in Figure 2, and is the same as used in the earlier study (Adams et al., 1960). The maneuver followed the flight path illustrated and the numbers represent the ten procedural items that had to be

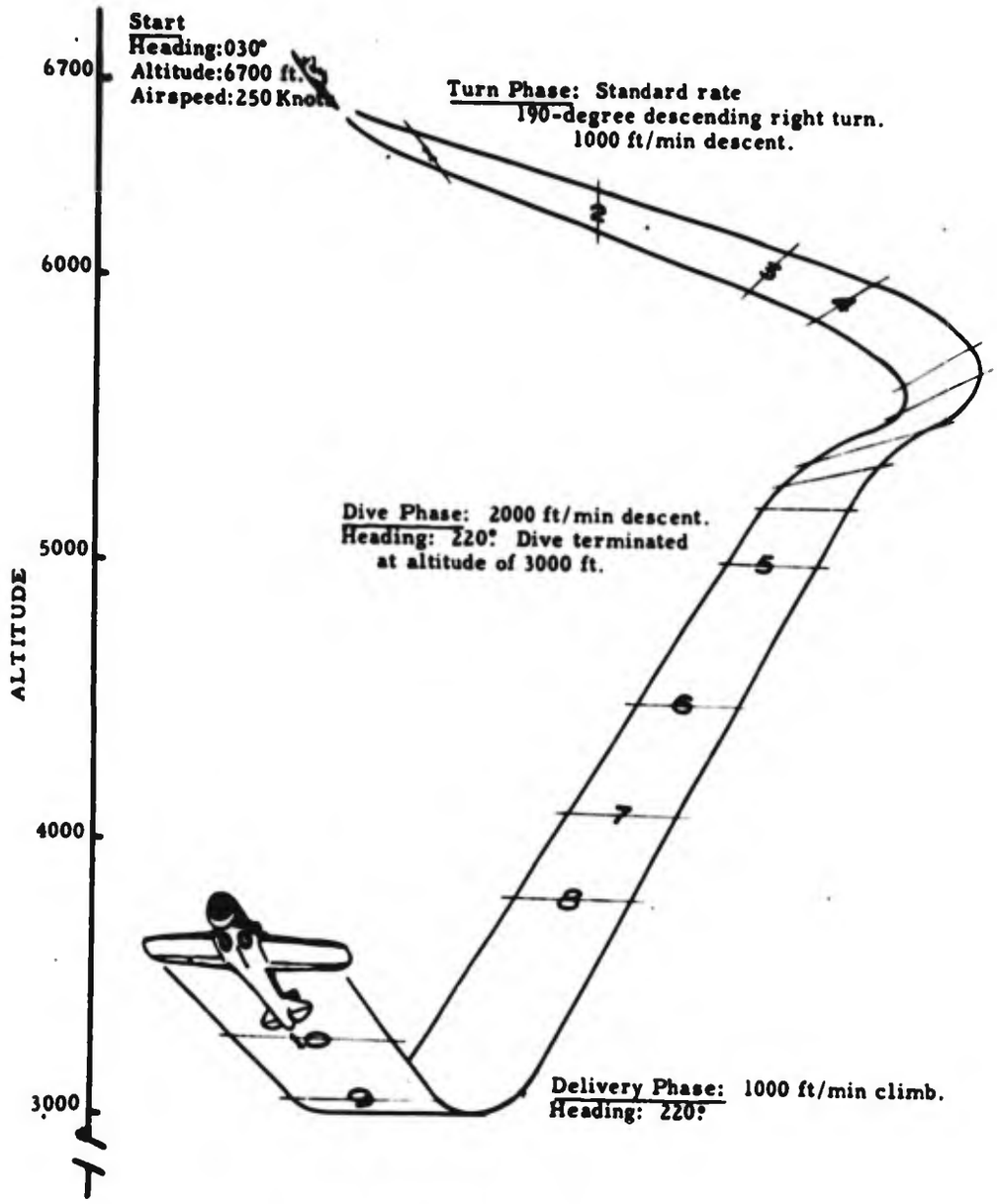

Fig. 2. A pictorial representation of the flight task.

made. This particular maneuver was designed to be demanding in flight control and procedures, and to place the subject under considerable time pressure so that there was a genuine requirement for concurrent time-sharing of procedures and flight control responses. The typical duration of the maneuver was three minutes.

The flight maneuver had three phases--Turn, Dive, and Delivery. The maneuver was started from an in-flight position of 6700 feet, heading of 030 degrees, and airspeed of 250 knots. The subject executed a 20-degree bank for a right-hand turn, descending at 1000 ft/min. throughout until a heading of 220 degrees was reached. At this point, which completed the Turn Phase, the heading was to be held at 220 degrees and the rate of descent increased to 2000 ft/min. and maintained to an altitude of 3000 feet, completing the Dive Phase of the maneuver. At 3000 feet, still on a heading of 220 degrees, the subject changed to a 1000 ft/min. climb, which began the Delivery Phase of the maneuver. The Delivery Phase was terminated after the subject's response to the final procedural item, and this ended the maneuver.

The procedural response portions of the flight task are designated in Figure 2 by the numbers 1 through 10. At Position 1, somewhere within the first 10 degrees of turn, the Pressure switch had to be turned on by the subject. At Position 2, and ten seconds past 040 degrees, the subject sent the following radio message via the cockpit microphone, "Homeplate, this is Red-Dog three, Tally-ho." At Positions 3 and 4, twenty seconds past 040 degrees, the Temp N and Voltage switches were turned on in that order. At Position 5 which is 5000 feet, the Timer switch was turned on and thirteen seconds past 5000 feet, at Position 6, the Fuse switch was required. At Position 7, passing through 4100 feet, the Detonator switch was turned on and passing through 3800 feet, at Position 8, the Critical switch was activated. At Position 9, when the red Toss Alert light on the instrument panel was illuminated by the experimenter, the Safety switch was turned on. Between 25-30 seconds past the occurrence of the Toss Alert light, at Position 10, activation of the Release switch was required.

Details of Experimental Sequence for Each Group

The single retraining session for each group is summarized in Table 1.

TABLE 1

Experimental Design

Group	10 Trials CPT Procedures Relearning	10 Trials Whole-task
Control	No	Yes
Experimental	Yes	Yes

In the original procedures learning study, the subjects were told that the research involved toss-bombing techniques to be used with a new Navy weapons delivery system. They were now told that the study had produced significant results and that the Navy had requested a repetition of aspects of the study in order to determine the reliability of the data.

Control group. The 10 subjects of this group were originally trained by the whole-task method. Each subject was reminded that the maneuver had involved a toss-bombing technique. He was asked to fly through the whole-task maneuver as accurately as he could from memory. It was explained that after each trial he would be informed of any mistakes in flight control and procedures and coached as to the proper responses. Ten whole-task trials were then flown, with knowledge of results given at the end of each trial.

Experimental group. The 10 subjects of this group had a portion of their original training in the CPT version of the SNJ OFT. Each subject was reminded that the maneuver had involved a toss-bombing technique. He was asked to get into the CPT and verbalize the maneuver at each step and perform each of the procedures as he came to it. Knowledge of results was given after each trial. Following 10 CPT trials, each subject was given 10 whole-task trials in the dynamic

OFT, just as the Control Group.

Method of Performance Recording

One experimenter scored only flight control responses and a second experimenter scored only procedural responses. Events happened too rapidly for one experimenter to do all of the recording accurately. The scoring assignments of each experimenter remained the same throughout the experiment. Standardized scoring sheets were used and are reproduced in Appendix A.

Flight parameters. Proficiency in flight control (accuracy of multi-dimensional tracking) is revealed in the extent to which basic flight instruments are kept aligned with a value defined as ideal for the maneuver. Bank and Vertical Speed were chosen as indices of proficiency in flight control. Bank was used instead of Heading because inadequacies in the computational mechanism of the trainer rendered heading values insensitive to small changes in Bank, thus making Heading a poor measure of proficiency in azimuth control.

Flight parameter values were recorded each time the experimenter observed a signal light on his console which flashed at ten-second intervals. The experimenter adhered to the following scoring procedure and obtained twelve measures for a flight parameter on a trial:

Turn phase. The timing device was started when the Bank first reached 10 degrees right and Bank and Vertical Speed were scored every ten seconds for thirty seconds.

Dive phase. The timing device was started when the altimeter indicated 5500 feet and Bank and Vertical Speed were scored every ten seconds for sixty seconds.

Delivery phase. When the altimeter first reversed direction at 3000 feet (ideally), the experimenter turned on the Toss Alert light, and at the same time, started the timing device. Bank and Vertical Speed were scored every ten seconds for thirty seconds.

Procedures. Procedural items were scored on an error-no error basis. The recording method distinguished between (a) the omission of an item, defined as failure of occurrence within the bounds of the criteria for the immediately preceding or the immediately following item, (b) a timing error where the correct response to an item was made but the timing criterion was not met, and (c) a correct response where all criteria were fulfilled.

The experimenter used the following rules for the correctness of procedures:

Procedure Number

1. Occurs within the first 10 degrees of turn.
2. Occurs 10 seconds $\pm$ 2 seconds after passing through 040 degrees.
3. Occurs 20 seconds $\pm$ 2 seconds after passing through 040 degrees.
4. Same as Number 3.
5. Occurs at 5000 feet, $\pm$ 20 feet.
6. Occurs 13 seconds, $\pm$ 2 seconds after passing through 5000 feet.
7. Occurs at 4100 feet, $\pm$ 20 feet.
8. Occurs at 3800 feet, $\pm$ 20 feet.
9. Occurs within 3 seconds after the experimenter turns on the Toss Alert light.
10. Occurs between 25 and 30 seconds after the appearance of the Toss Alert light.

A non-correction method of scoring was used, i.e., the first occurrence of a procedural item was the one evaluated and a subsequent change in the switch position did not alter the score.

Subjects

The experimenters were able to locate twenty of the thirty male subjects who participated in the original procedures learning study. Of the twenty, ten had been Control and ten Experimental subjects. All held valid private pilot's certificates. Two subjects had had a combined total of six hours of instrument instruction since original learning 10 months earlier, but no subject had any interim experience in either the

SNJ aircraft or the SNJ OFT. No subject had more than one hundred hours of light plane flying time.

Experimenters

Two experimenters were used. Both were graduate students in engineering psychology. One was an experienced Link trainer instrument instructor and commercial pilot. The other had participated in the Naval Air Cadet training program and had light plane experience.

RESULTS

Method of Scoring

Procedures. A pilot could respond to a procedural item in three basic ways: (a) omit it, (b) include it but fail to have it occur in the proper place in time, and (c) include it and have it occur in its proper place in time. The timing criterion for each procedural item has been presented in the previous section. An omission was defined as the complete failure of an item to occur anywhere in the bounds defined by the immediately prior and the immediately following item. On the basis of these considerations, the following scoring weights were used for an item:

Score	Behavior criterion
0	omission
1	item occurred but had a timing error
2	item correct

With a maximum of two points for each item, the ten procedural items allowed a total score of 20.

Flight parameters. Bank and Vertical Speed were the measures of proficiency in flight control. Each of these parameters was recorded at 10-second intervals. The error for each parameter at each recorded point was determined as the absolute deviation from the value of the

parameter specified as ideal at that phase of the maneuver. Absolute error values were summated for each phase on a trial and divided by the number of measurements within the phase. The resultant mean error values were summed over the three phases for each trial and divided by three in order to obtain a representative mean error value for a phase on a trial. This mean absolute error score was the subject's index of proficiency on that parameter for the trial.

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

Experimental Findings

Procedures. Figure 3 shows the performance curves for procedures. The data are plotted in terms of per cent correct based on the total possible score of 20. On the left-hand side of the figure are the performance curves for the criterion transfer trials (15-26) where both groups practiced the whole-task in the SNJ OFT in the first study (Adams et al., 1960) where procedures were originally learned. The 10 trials on the right-hand side of the graph show performance of the procedural response in the present retention study, and both the CPT practice of the Experimental Group and the whole-task practice of both groups in the SNJ OFT are represented. One of the striking features of the data is that the forgetting of procedures is virtually complete over the retention interval of 10 months. At the completion of original learning the Control Group was 95 per cent correct but on the first retention trial their performance is only at the level of five per cent correct. This is evidenced too in the CPT performance curve of the Experimental Group which has about the same initial level as the Control Group and closely parallels the reacquisition of procedures by the Control Group, although the performance of procedures apparently is easier in the CPT because it finally attains 100 per cent proficiency on Trial 8 while the Experimental Group appears to stabilize in the region of 90 per cent.

The CPT is undeniably a useful training device because the initial whole-task trials for the Experimental Group are clearly superior to performance by the Control Group on corresponding trials. Table 2 presents t tests for independent measures of the mean difference between the two groups on Trials 1, 2, 3, and 4. The Experimental Group is significantly superior to the Control Group on all of these trials.

TABLE 2

t Test of the Mean Differences Between Groups for Procedures on the First Four Whole-task Relearning Trials

Trial	Group	Mean Score	Mean Difference	t	Reliability of Difference
1	Control Experimental	0.9 14.5	13.6	9.25	$p < .01$
2	Control Experimental	5.4 16.8	11.4	8.64	$p < .01$
3	Control Experimental	10.3 18.4	8.1	3.65	$p < .01$
4	Control Experimental	15.3 18.5	3.2	2.66	$p < .02$

Of fundamental interest for the time-sharing hypothesis is a comparison of the Experimental Group's performance on the final trial (26) of whole-task practice and the first whole-task trial 10 months later following CPT refresher training. If time-sharing is not a critical variable we can expect the first relearning trial to be at about the same level as Trial 26. Figure 3 shows this not to be true. Performance on the first two relearning trials is below that on Trial 26

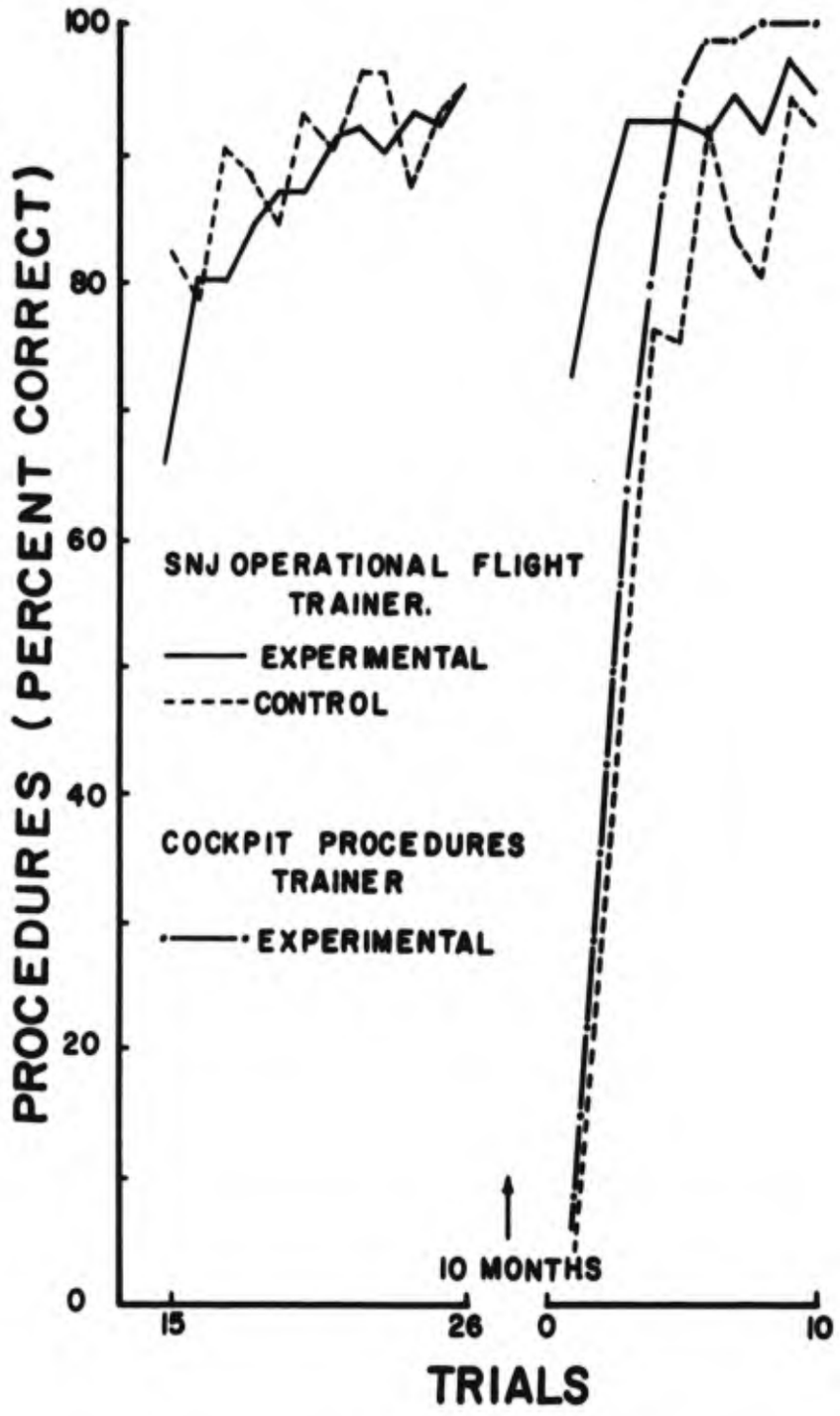

Fig. 3. Performance of the two groups in the procedural response sequence. Trials 15-26 are final whole-task trials of the original study. Trials 1-10 represent the whole-task relearning trials of the present study. Also shown is the part-task response sequence of the Experimental Group in the CPT.

and Table 3 shows that the mean differences, as tested by the t test

TABLE 3

t Test of the Mean Differences
Between the Final Transfer Trial (26) of the Original
Study and Each of the First Four Trials of the Relearning Study
for Procedures Scores of the Experimental Group

Relearning Trial	Mean Difference	t	Reliability of Difference
1	4.8	3.26	$p < .01$
2	2.5	3.43	$p < .01$
3	0.9	1.55	NS
4	0.8	1.86	NS

for related measures, to be statistically significant. By Trial 3, however, the mean difference is non-significant and this indicates that for our experimental task two trials of whole-task practice must follow CPT refresher training in order to regain the level of proficiency in procedures held at the start of the 10 months retention interval. It does not seem that the failure of the Experimental Group to attain its original level of whole-task proficiency can be attributed to an insufficient amount of CPT practice because CPT performance was at 100 per cent on the last three trials. We must conclude that time-sharing is a variable in relearning, just as in original learning, and CPT practice by itself is inadequate to restore fully the forgotten procedures. Some whole-task practice must follow CPT practice in order to learn the time-sharing aspects of the complex behavior and re-establish the level of performance prevailing at the start of the retention interval.

Bank parameter. Figure 4 is the performance curves for the two groups plotted in terms of the mean absolute bank error in degrees. Trials 15-26 of the original study and Trials 1-10 of the present study are shown. There is a close correspondence between groups in Bank control ability.

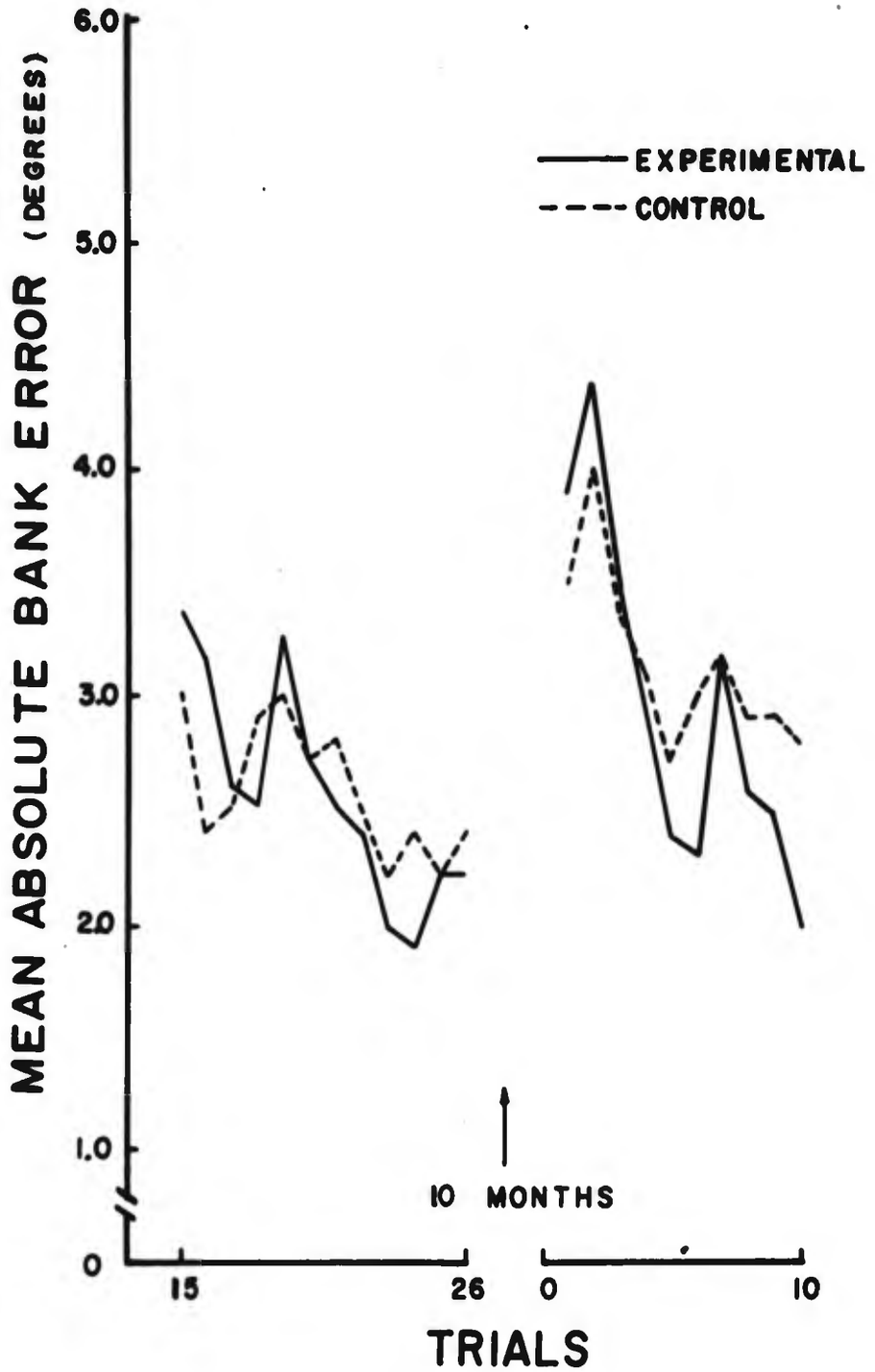

Fig. 4. Performance of the two groups on the bank parameter for the original study (Trials 15-26) and the present study (Trials 1-10).

Table 4 presents the results of t tests for independent measures to test the statistical significance of the mean difference between groups on Trials 1, 2, 3, and 4. None of the t ratios are statistically significant. The essential similarity of the two groups shows an independence of procedures and control of the Bank parameter because the 10 trials of CPT refresher practice for the Experimental Group had no transfer effects whatsoever to the measure of proficiency in the Bank flight parameter.

TABLE 4

t Test of the Mean Difference Between Groups for the Bank Parameter on the First Four Whole-task Relearning Trials. The Score Unit is Degrees

Trial	Group	Mean Score	Mean Difference	t	Reliability of Difference
1	Control	3.5	0.4	0.51	NS
	Experimental	3.9			
2	Control	4.0	0.4	0.23	NS
	Experimental	4.4			
3	Control	3.4	0.1	0.46	NS
	Experimental	3.5			
4	Control	3.2	0.2	0.29	NS
	Experimental	3.0			

An earlier study on the forgetting of instrument flying skills (Mengelkoch et al., 1958) demonstrated that a pilot's response capability in flight control is relatively stable over a retention interval of four months, and Figure 4 reveals the same general tendency for Bank even when the retention interval is increased to 10 months.

While Table 5 shows a statistically significant loss in proficiency over 10 months for the Experimental Group, the mean increase in error over the retention interval is only 1-2 degrees and this hardly can be construed as having practical, operational significance for flight training.

TABLE 5

t Test of the Mean Difference Between the Final Transfer Trial (26) of the Original Study and the First Trial of the Relearning Study for Error in Controlling the Bank Parameter

Group	Trial Means	Mean Difference	t	Reliability of Difference
Control	Trial 26: 2.2 Trial 1: 3.5	1.3	1.88	NS
Experimental	Trial 26: 2.0 Trial 1: 3.9	1.9	2.34	$.01 < p < .05$

Vertical Speed parameter. Figure 5 shows the performance curves for the two groups plotted in terms of the mean absolute vertical speed error in feet per minute. Trials 1-10 are the whole-task Vertical Speed control performance of the present relearning study, and Trials 15-26 are the whole-task Vertical Speed control performance of the original study. Both groups have a substantial decrement after 10 months, and Table 6 shows that forgetting loss is statistically significant for each group. It is not clear why Vertical Speed should show such a large decrement, particularly since the experimental work on the forgetting of instrument flying skills (Mengelkoch et al., 1958) shows flight control to have a good degree of resistance to forgetting. However, that forgetting study did not have Vertical Speed

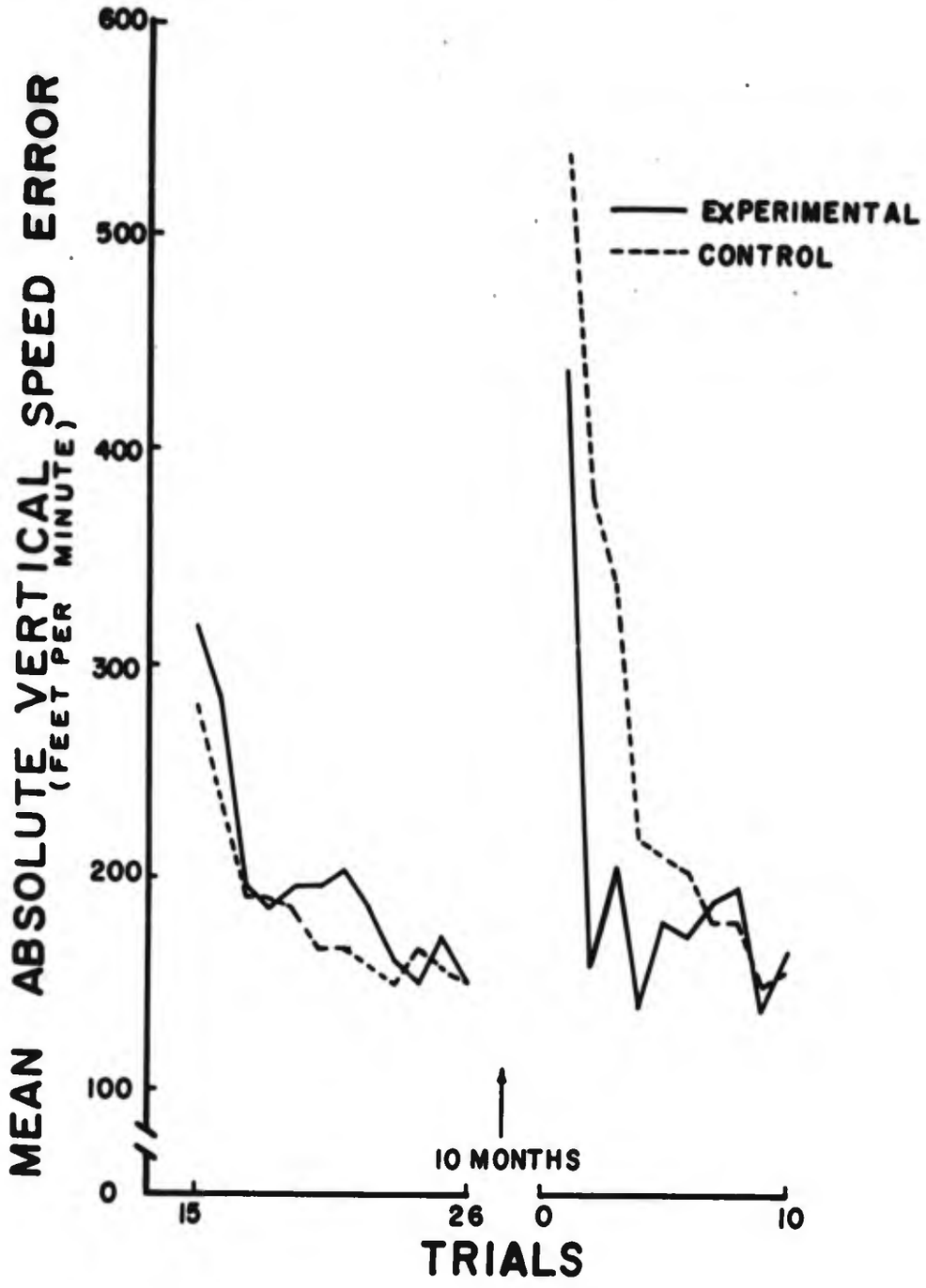

Fig. 5. Performance of the two groups on the vertical speed parameter for the original study (Trials 15-26) and the present study (Trials 1-10).

as one of the measured flight parameters. It would appear that Vertical Speed is unusual for a flight instrument in showing such a large forgetting loss. One possible interpretation of this discrepancy is that the Vertical Speed instrument is much more difficult to control than other flight instruments by virtue of its sensitivity and lag characteristics. The occurrence of a relatively small error in movement, or a slight failure to anticipate the lag properly, could result in a large recorded error value in feet per minute. The pilot's response error arising from forgetting may be small but the poor human engineering of this instrument produces a large measured error for the total man-machine system in the vertical speed dimension.

TABLE 6

t Test of the Mean Difference Between the Final Transfer Trial (26) of the Original Study and the First Trial of the Relearning Study for Error in Controlling the Vertical Speed Parameter

Group	Trial Means	Mean Difference	t	Reliability of Difference
Control	Trial 26: 154.0 Trial 1: 542.5	388.51	4.50	$p < .01$
Experimental	Trial 26: 137.3 Trial 1: 439.6	302.31	4.65	$p < .01$

The two groups appear to differ in the trend of their relearning curves. The Experimental Group's performance had a forgetting decrement only on Trial 1. By Trial 2 the level of performance achieved 10 months earlier had been completely reacquired. In contrast, the Control Group had a trend of slightly higher decrement on

Trial 1 and this trend of poorer performance persisted over the initial trials. Table 7 gives the results of the t test for independent measures of the mean difference between groups on the first four relearning trials.

TABLE 7

t Test of the Mean Difference Between Groups for the Vertical Speed Parameter on the First Four Whole-task Relearning Trials. The Score Unit is Feet per Minute

Trial	Group	Mean Score	Mean Difference	t	Reliability of Difference
1	Control Experimental	542.5 439.6	102.9	1.04	NS
2	Control Experimental	378.2 160.9	217.3	3.34	$p < .01$
3	Control Experimental	338.6 204.6	134.0	1.53	NS
4	Control Experimental	217.2 141.2	76.0	2.16	$.02 < p < .05$

The Control Group has significantly poorer performance on Trials 2 and 4. Evidently CPT practice for the Experimental Group had a moderate positive transfer effect to the control of Vertical Speed, but why the practice of the discrete procedural response sequence should influence the continuous control of Vertical Speed is speculative. Two principal possibilities are suggested:

a. The presence of a procedural response element in aspects of continuous flight control. Sometimes it is forgotten that multi-dimensional tracking in instrument flying involves more than just error-nulling in several task dimensions but, in addition,

requires the pilot to know what tracking sequences should be performed and when they should be initiated. Knowledge of what to do and when to do it represents selective procedural response acts but the accuracy of the actual performance of a selected sequence is dependent upon the pilot's tracking skill. Granting this, we would expect the Experimental Group to benefit from CPT practice which included information about the phases of the toss-bomb maneuver within which the 10 primary procedural responses occurred. The Control Group, on the other hand, executed Trial 1 completely on the basis of recall and their forgetting of the ideal values of flight control parameters could inflate their error scores in flight control. The experimenters observed this to be the case with some subjects. A subject might remember, for example, that a right-hand descending turn started the maneuver but he would not remember the correct descent rate of 1000 feet per minute. The tendency, therefore, was to set up a "safe" rate of descent that was not too difficult and demanding, e.g., 500 feet per minute, which gave a substantial error in the Vertical Speed measure. It is interesting to note in Figures 3 and 5 that the relearning of procedures and Vertical Speed for the Control Group follow the same general course and each takes about five trials to regain the level of proficiency held 10 months earlier. While this may only be a fortuitous correspondence, it may indicate that the reacquisition of proficiency in Vertical Speed flight control is primarily based on the procedural component response of the Vertical Speed measure of when and what to do during each phase of the maneuver.

The failure of a difference between the two groups to occur in their relearning of the Bank parameter might be considered as evidence against this interpretation, but a "safe," routine degree of bank for a turn in most aircraft is about 20 degrees, and this was what the maneuver required in the Turn Phase. As long as a subject in the Control Group remembered that the maneuver

began with a turn, it is reasonable to expect that he would use about a 20-degree bank because of his past experience as a private pilot.

b. The Control Group's relearning of procedures did not permit sufficient attention to Vertical Speed. The sensitivity and lag characteristics of this flight instrument make it much more difficult to control than the other flight instruments. During the early relearning trials we can surmise that the pilot, by having to give more time to procedures, neglected Vertical Speed from time to time and a greater than usual amount of error was generated because of this inattentiveness. As the procedures became learned, more time could be devoted to controlling the difficult Vertical Speed parameter and error decreased. This would seem to account for the general paralleling of the relearning curves for procedures and Vertical Speed. The rapid learning of Vertical Speed for the Experimental Group also somewhat parallels its rapid reacquisition of procedures in the whole-task performance of the maneuver. In general, the relearning of the sensitive Vertical Speed parameter is synchronized with the relearning of procedures.

This is a time-sharing hypothesis and it might seem that the Bank parameter should reveal its effects too. Yet this measure revealed no difference between groups in the relearning trials. One possibility is that Bank is more stable and can better withstand the momentary inattention occasionally enforced during the relearning of procedures.

There is no basis at this time for choosing between these two hypotheses. Empirically, the superiority of the Experimental Group in Vertical Speed during the early relearning trials indicates a positive transfer effect from CPT practice, but the means by which this transfer occurs in the complex flying task cannot be clearly established.

Serial position effects. One of the most commonly observed phenomena in the serial learning of verbal materials is the bowed serial position curve where the level of performance is lower in the center of a sequential list during learning and recall than at either end (McGeoch and Irion, 1952). Figures 6 and 7 show the per cent correct on Trials 1 - 4 for each of the 10 procedural items as a function of its position in the sequence, and it is of interest to note that the bowed curves traditionally found in the learning of verbal lists also appear in the performance of aircraft procedures within the context of the complex flying task. The recall of items at the beginning and end of the list is superior to those in the center, and this well-known trend is found in the data of both groups.

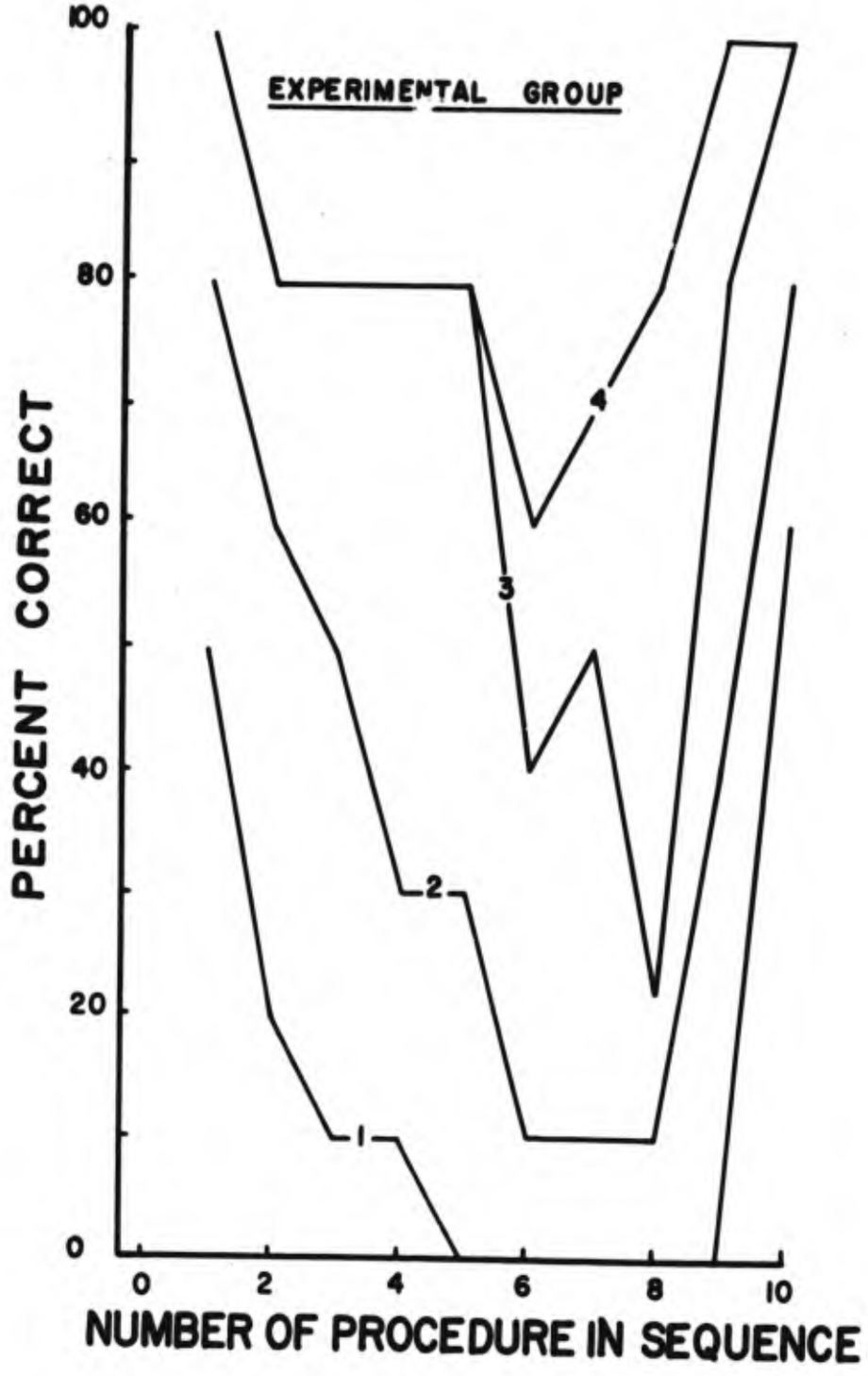

Fig. 6. Retention of procedures over a ten-month period is shown by the per cent correct on each of the first four relearning trials as a function of serial position of items. Curves exhibit classical serial position bowing effect.

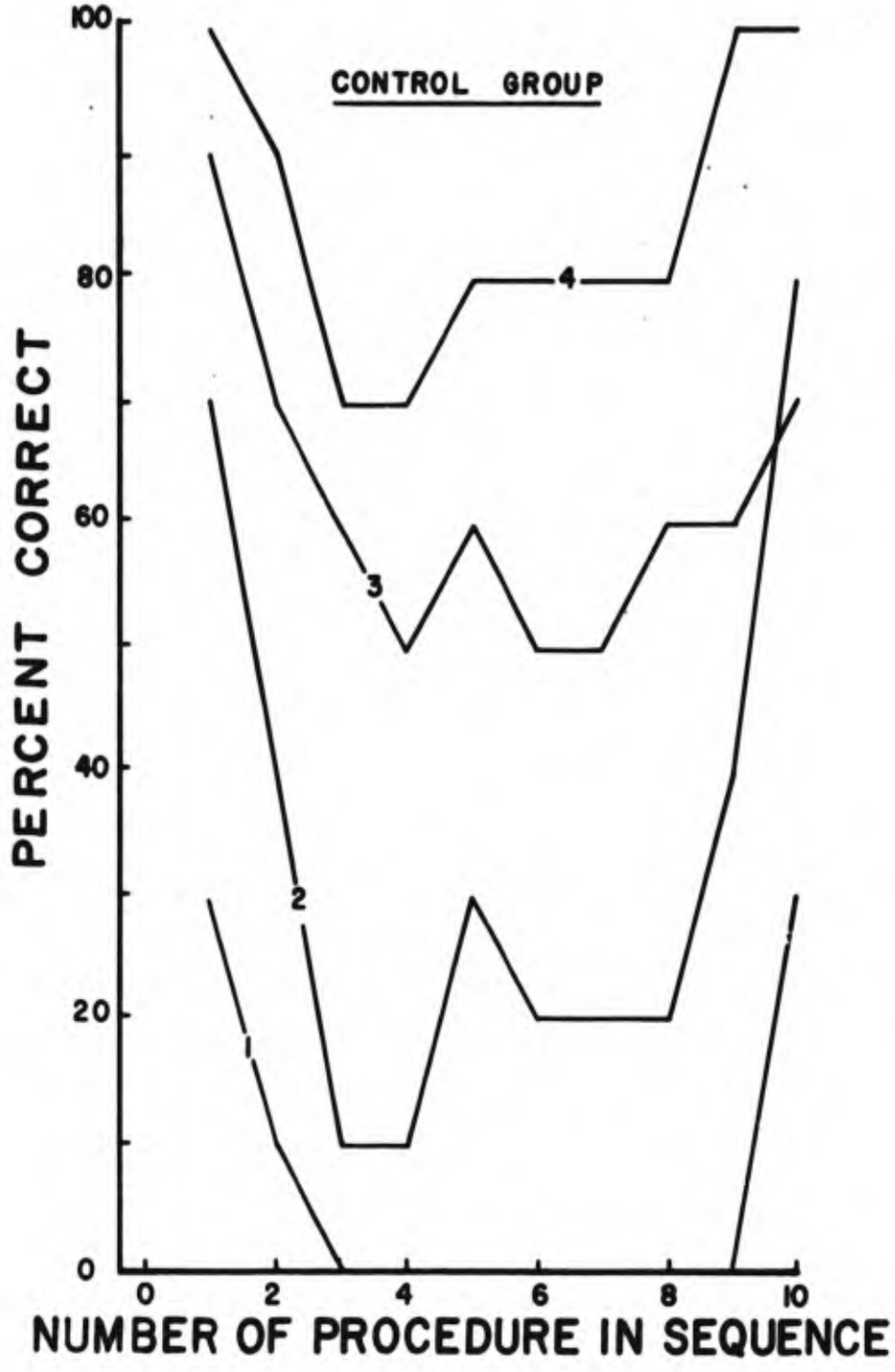

Fig. 7. Retention of procedures over a ten-month period is shown by the per cent correct on each of the first four relearning trials as a function of serial position of items. Curves exhibit classical serial position bowing effect.

DISCUSSIONS AND CONCLUSIONS

An earlier study (Adams et al., 1960) on the role of time-sharing in the design and use of CPTs found that learning procedural responses in a CPT without the concurrent practice of flight control responses impaired the amount of transfer when the procedures had to be performed in the dynamic whole-task flying situation. These findings were taken in support of the time-sharing hypothesis that states a learned interaction between flight control and procedural responses when they have to be performed concurrently in the complete flying task. The experiment reported here was a follow-up investigation where most of the subjects of the original study were recalled to participate in a recall session with the purpose of checking whether a CPT, while having shortcomings for the original learning of procedures, may be completely effective for the relearning of procedures after they have been partially forgotten. It is plausible that the time-sharing aspects of complex behavior have good resistance to forgetting and that the restoration of forgotten procedures could be completely accomplished by a CPT. If true, this could have extensive implications for maintenance of proficiency in normal and emergency procedures for aircrew personnel. The growing reliance on automatic and semi-automatic subsystems in modern manned aircraft is placing an increasing emphasis on procedural and decision-making activities for the human operator. Forgetting makes the human operator an unstable component in any complex man-machine system and it is necessary to perform periodic training actions that will re-establish the performance level reduced by forgetting processes.

Our findings revealed that the forgetting of procedures was almost complete over a retention interval of 10 months, which is consistent with other laboratory work on the forgetting of discrete response sequences (Neumann and Ammons, 1957). From a proficiency level of 95 per cent correct at the start of the retention interval the performance dropped to about the five per cent level 10 months later. Practice on the CPT

was found to be very beneficial and greatly enhanced the performance of procedures when they were performed as part of the toss-bomb maneuver in the SNJ OFT which served as the criterion task. However, the level of whole-task performance in procedures after CPT practice was significantly below that held 10 months earlier at the onset of the retention interval. The earlier performance level was re-established after two trials of additional practice in the OFT, but this requires us to reject the hypothesis that a CPT can be completely effective in reinstating the level of procedures that must be performed in a time-shared relationship with flight control activities. We must conclude that time-sharing is a factor for the relearning of forgotten procedures just as it is for original learning. A CPT is not a sufficient training device for complete restoration of procedures that must be performed in a time-shared relationship with flight control responses. Just as with original learning, some additional whole-task practice is required before proficiency is maximized.

The primary function of training research is to identify and determine the role of variables for learning, transfer of training, and retention, and this study has shown that the time-sharing variable limits the scope of usefulness for CPTs. In two studies we have shown that some integrative whole-task practice must follow procedural sequences learned in a CPT. The aircraft, being the criterion task, of course is ideal for whole-task practice, but there are classes of procedures, such as dangerous emergencies, which cannot be effectively practiced in the air. A further limitation on air practice occurs with a single-place aircraft that does not have another crew member aboard to act as a safety monitor while the pilot is practicing his procedures. It would appear, therefore, that an OFT is the best training device to provide the post-CPT whole-task integrative practice. Virtually all procedures and their cues can be presented for practice in a well-designed OFT and they can be repeatedly practiced in their time-shared relationship with other ongoing responses at low cost and with perfect safety. CPTs are unquestionably useful training devices but they must

be used along with an OFT, which also trains procedures, and this represents a duplication of training function. Since all of the training could be accomplished on an OFT, the primary functions of the CPT would be to reduce OFT utilization time; and to provide training prior to the arrival of the OFT. Consideration should be given also to very simple CPTs, such as photographic cockpit mockups, which have been shown to yield training benefits as large as CPTs having realistic hardware cockpits (Dougherty et al., 1957). The evidence is that all procedures which do not have to be time-shared with flight control could receive large benefits from practice in a simple photographic device. The time-shared procedures will have to be practiced in the air or in an OFT, but the photographic cockpit mockup gives good training benefits at a cost low enough to be used along with an OFT without major concern for some duplication in training function.

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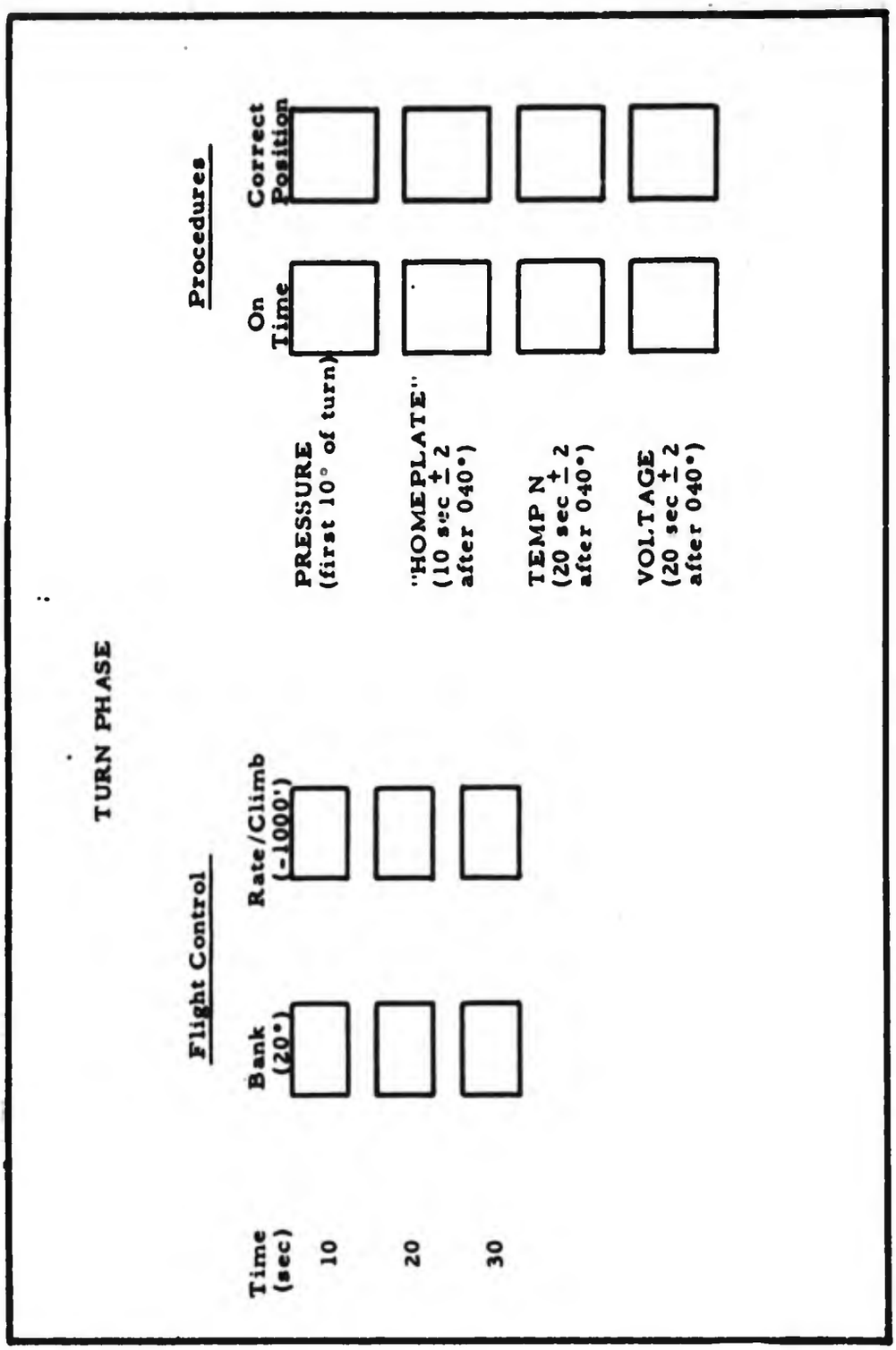
APPENDIX A

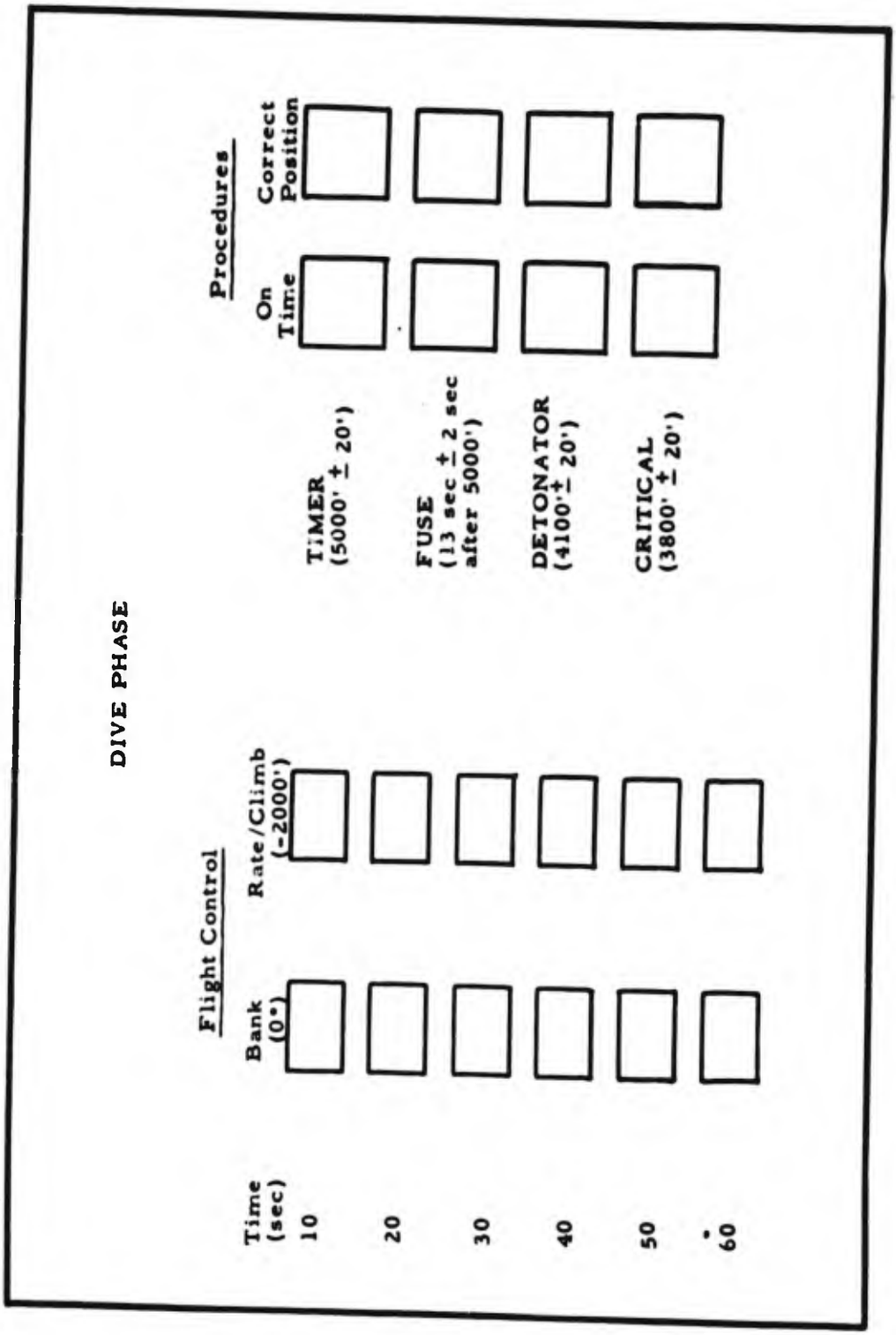
DATA SHEETS FOR RECORDING FLYING PROFICIENCY IN PROCEDURES AND FLIGHT CONTROL IN THE THREE PHASES OF THE HYPOTHETICAL TOSS-BOMB MANEUVER

1. TURN PHASE
2. DIVE PHASE
3. DELIVERY PHASE

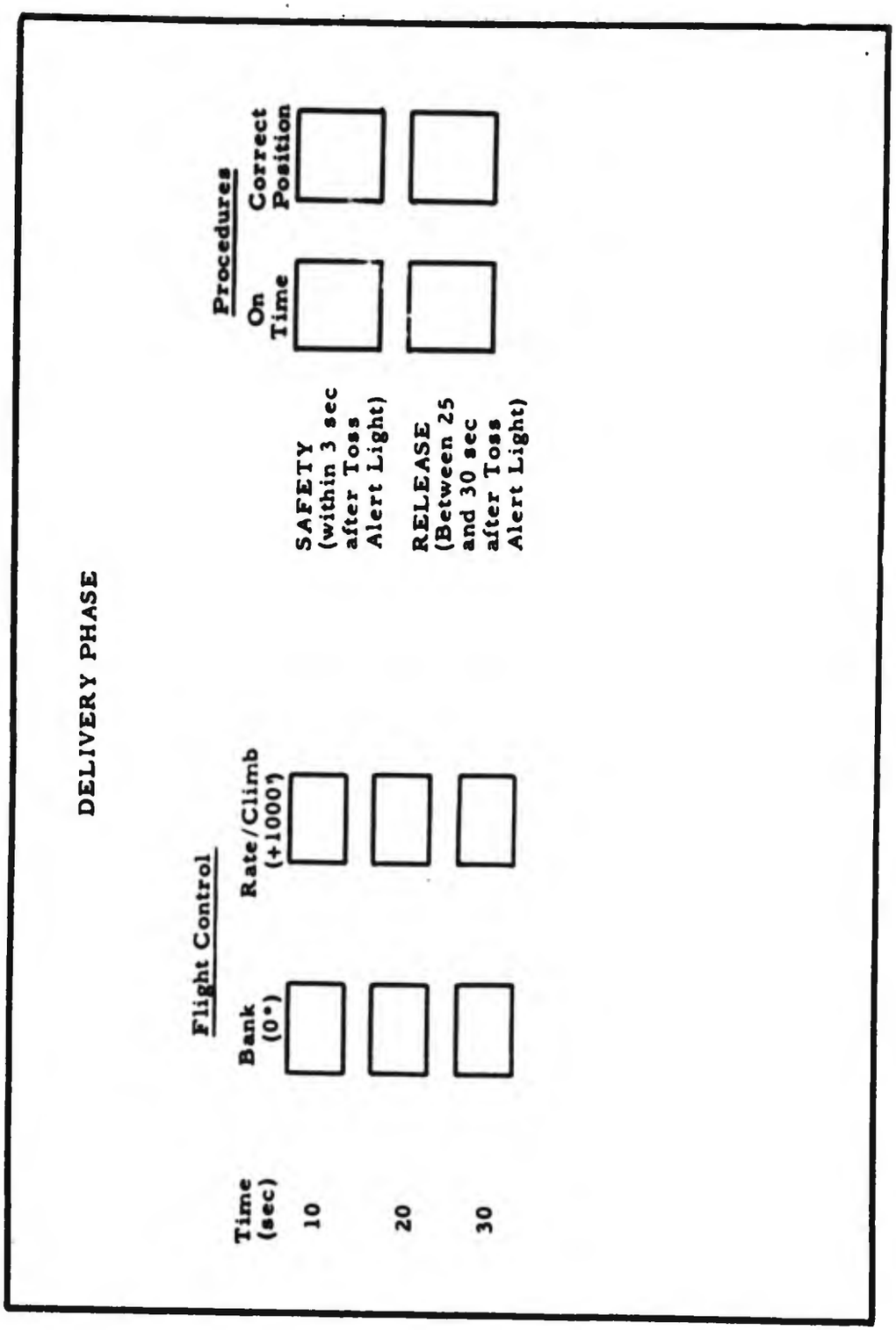
APPENDIX A


TURN PHASE
Flight Control
Procedures
Time (sec)
Bank (20°)
Rate/Climb (-1000')
On Time
Correct Position
10
20
30
PRESSURE (first 10° of turn)
"HOMEPLATE" (10 sec ± 2 after 040°)
TEMP N (20 sec ± 2 after 040°)
VOLTAGE (20 sec ± 2 after 040°)

APPENDIX A


DIVE PHASE
Flight Control
Bank (0°)
Rate/Climb (-2000')
Procedures
On Time
Correct Position
TIMER (5000' ± 20')
FUSE (13 sec ± 2 sec after 5000')
DETONATOR (4100' ± 20')
CRITICAL (3800' ± 20')
Time (sec)
10
20
30
40
50
60

APPENDIX A


DELIVERY PHASE
Time (sec)
Flight Control
Bank (0°)
Rate/Climb (+1000')
10
20
30
Procedures
On Time
Correct Position
SAFETY (within 3 sec after Toss Alert Light)
RELEASE (Between 25 and 30 sec after Toss Alert Light)

APPENDIX B

TABLE 8

Scores for Procedures and Flight Parameters on Each Trial of Whole-task Practice in the SNJ OFT

(The procedures measure is a raw score based on a weighted scoring method yielding a maximum score of 20. Bank is in degrees; Vertical Speed in feet per minute.)

	Experimental Group			Control Group		
Trial	Procedures	Bank	Vertical Speed	Procedures	Bank	Vertical Speed
1	14.5	3.9	440	0.9	3.5	542
2	16.8	4.4	161	5.4	4.0	378
3	18.4	3.5	205	10.3	3.4	338
4	18.5	2.9	141	15.3	3.1	217
5	18.3	2.4	178	15.0	2.7	210
6	18.2	2.3	167	18.5	3.0	203
7	18.7	3.2	186	16.6	3.2	176
8	18.2	2.6	193	16.1	2.9	175
9	19.4	2.5	133	18.7	2.9	144
10	18.8	2.0	160	18.4	2.8	152

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A5	(9)	H5	(2)	J37	(1)	W3A	(1)	W7E	(2)
A6	(3)	H8	(2)	J47	(2)	W3B	(1)	W7X	(1)
B1	(3)	H24	(1)	J60	(1)	W3C	(1)	W10A	(1)
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