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EVALUATION OF A LOW FIDELITY SIMULATOR (LFS) FOR INSTRUMENT TRA--ETC(U)

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EVALUATION OF A LOW FIDELITY SIMULATOR (LFS) FOR INSTRUMENT TRAINING

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The objective of this study was to investigate the transfer of training from a low fidelity simulator (LFS) to a higher fidelity device, and subsequently to the aircraft. An attempt was made to determine both the magnitude of transfer, as well as the temporal duration of the effect. A transfer of training design was employed using 14 students entering Undergraduate Pilot Training (UPT). Subjects were divided into two equal groups (n = 7). One group received pretraining on the LFS, while the other did not. LFS training consisted of 10 hours of basic instrument instruction conducted over a 2-week period prior to UPT entry. During LFS training, students were advanced on a proficiency basis, using objectively derived scoring procedures.

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Upon entering the UPT program, both groups were required to fly an evaluation sortie in the Advanced Simulator for Pilot Training (ASPT). The sortie consisted of two repetitions of six instrument flight maneuvers. All students then entered normal T-4 instrument training, during which task frequency data were collected. Prior to entry into the T-37 aircraft training phase, both groups again flew the same evaluation sortie in the ASPT. Task frequency data were then collected in the T-37 up to each student's first solo flight.

On the initial evaluation sortie in the ASPT, the LFS-trained group performed significantly better than the control group across all maneuvers. Analysis of the collected data during T-4 training revealed significantly fewer trials to criterion for the experimental groups. On the second ASPT sortie, however, no differences were found between the groups. Likewise, the data collected during T-37 training revealed no differences.

The results indicated a considerable amount of positive transfer at the onset of the UPT program. These initial performance differences, however, appeared to wash out following approximately one month of academic and T-4 simulator training. Beyond this point, no differences between the two groups could be detected.

PREFACE

This report represents a portion of the research program of project 2313, Human Resources; task 2313T5, Information Processing and Cognitive Components of the Flying Task. The study was conducted jointly by Arizona State University, Tempe, Arizona, and the Flying Training Division, Air Force Human Resources Laboratory, Williams Air Force Base, Arizona, under a grant from the Air Force Office of Scientific Research. Support was provided by members of the 82nd Flying Training Wing, Deputy for Operational Research staff.

The conduct of this research would have been impossible without the assistance of Capts Lesher and Rowe who provided instruction in the LFS. The assistance of Mr. Lynn Thompson is also acknowledged for the development of the necessary software for the ASPT data collection sorties.

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EVALUATION OF A LOW FIDELITY SIMULATOR (LFS) FOR INSTRUMENT TRAINING

I. INTRODUCTION

Since the early beginning of aircraft flight training, the term "simulator" has been used by training personnel to describe flight trainers, albeit with some confusion. In an early paper, Gagne (1954) described simulation in terms of:

> "...Big or small, complex or simple, the simulator is believed by its designer, and hopefully by its users, to provide exact representations of certain parts of the real 'operations situation.' In this respect, a simulator is often distinguished from a trainer. While a simulator is often used for training, there are specific trainers which do not represent any specific real situation and which are not designed to do so...."

In his early description of simulation, Gagne appeared to differentiate training purpose via the use of two terms: simulator and trainer. Other investigators have been concerned with similar distinctions.

Miller (1954) for example, drew a sharp distinction between engineering and psychological simulation. In his view, engineering simulation closely duplicated the functional characteristics of the operational equipment, while psychological simulation was concerned with transfer of training. Building on Miller's earlier physical and psychological distinction, Muckler, Nygaard, Kelly, and Williams (1959), in their work on the psychological variables in flight simulation, further differentiated physical and psychological simulation. They identified two areas of general interest present in the design, construction, and utilization of synthetic training devices–fidelity and training value. Fidelity, they hold, describes the degree of physical simulation or representation that may exist between the training device and the operational aircraft. They suggest this area falls within the domain of the design engineer and is primarily a hardware or physical simulation factor. Their second area of interest, and of greater concern here, is the training value that results from the use of the simulation device. This second area has as its focus the psychological aspects or transfer of training from one simulation device to another and/or from the simulator to the aircraft.

In an earlier report, Parker and Downs (1961) identified aircraft flight simulators and full mission simulators as two general types of simulation devices used in pilot training. Their distinction fits well within the contemporary distinction of part-task versus full mission capabilities. In the part-task flight simulator, relevant control dynamics are present, although the system may or may not include visual and/or motion systems. Additionally, although not necessarily, the simulator may be a realistic physical replica of the aircraft. A prototypical example of a part-task device is the operational T-4 simulator used for ground-based instrument and cockpit procedures training in Air Force pilot training. Another example of a part-task simulation device is the USAF/HRL Formation Flight Trainer (FFT). The FFT is a fixed-base simulator with a projected wide-angle visual system providing realistic two-aircraft formation flight situations (Reid, 1975).

Full mission simulators, on the other hand, permit the student pilot to receive instruction and practice complete missions. For example, the Advanced Simulator for Pilot Training (ASPT) is a full mission simulator and is considered a high fidelity device. In other words, all tasks done in the aircraft can be accomplished in the simulator. The student can practice ground check, takeoff, navigation, airwork, formation flight, ground-controlled approach (GCA), etc. under full visual and motion conditions.

Valverde (1968, 1973) points out that flight training simulators have progressed from the relatively simple devices in use prior to and during World War II to the present high fidelity, computerized operational systems that virtually replicate the aircraft. An important question to keep in mind during spiraling simulator costs is the transfer of training value derived from the use of such devices. Hopkins (1975), for example, criticizes the contemporary approach to simulation in that cost effectiveness has not been demonstrated for many of today's special simulator features.

What are some alternatives to expensive, high fidelity aircraft simulation? Are there opportunities to jointly apply today's engineering and behavioral science knowledge to the design, construction, and application of effective low-cost, part-task simulation devices? To address these questions, an inexpensive low fidelity simulator (LFS) with an objective computer-scoring metric was developed. The approach stressed the psychological aspects of flying training. Therefore,

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transfer of training became the key issue. In the end result, the appraisal of any training device must consider how effectively simulator training transfers to the aircraft. Within this perspective, several theoretical questions were of interest.

First, it is important to determine whether or not the skills required to fly the low fidelity simulator are consonant with the skills required to fly other simulators, as well as the aircraft. If the low fidelity device requires relevant flying skills, then persons with increasing amounts of flying experience should achieve higher performance scores in a fewer number of trials. Conversely, persons with lesser amounts of previous flying experience should require a greater number of trials to approach and/or attain a given performance level. In a preliminary study four acquisition curves were obtained to support the expectation that the LFS device does indeed tap the pilot's relevant flying skills repertoire. The data were obtained using a simple straight-and-level maneuver, and indicate previous piloting experience to be significantly related to proficiency on the LFS.

Second, what is the type and magnitude of transfer from the LFS to a higher fidelity device and, subsequently, to the aircraft? If training on the LFS device assists the student pilot in the acquisition of relevant flying skills, then these skills should transfer positively to a high fidelity simulator and to the aircraft.

Third, in the event of positive training transfer to a higher fidelity device, what is the temporal duration of this effect? In other words, how much training is required before these transfer effects are "washed out" in the sense that the performance of students without the pretraining is equivalent to performance of students with the LFS training? The present study attempted to provide answers to these latter two questions.

II. METHOD

Subjects

Two groups of seven subjects were employed. Both groups consisted of student pilots entering the Undergraduate Pilot Training (UPT) program at Williams Air Force Base. All subjects had various amounts of previous light aircraft flying experience with no prior jet aircraft experience reported. Members of the control group were selected to match the members of the randomly selected experimental group, using a similar number of hours of previous flying experience as the criterion.

Apparatus

Low Fidelity Simulator (LFS). This simulation device consists of a spring-centered joystick mounted to a straight-backed chair. The joystick, responsive to x-y pilot input, simulates pitch-and-roll controls, while an adjacent mounted lever serves as a simulated throttle. An abbreviated instrument panel, displayed via a small cathode ray tube (CRT), consists of a series of computer-generated images indicating airspeed, percent power, heading, attitude, vertical velocity, and altitude. A small laboratory digital computer, programmed with the appropriate flight-dynamics equations, receives the pilot's input from the throttle and joystick controls and, in turn, drives the simulated instrument panel in real-time and in the correct interactive dynamic sequence found in the actual aircraft. The flight-dynamics equations and system development are those of the T-38 aircraft and are described elsewhere (see Leshowitz & Nielson, 1975). Figure 1 provides an annotated representation of the abbreviated instrument panel. The LFS device and its objective computer scoring metric were used in preUPT training.

Advanced Simulator for Pilot Training (ASPT). The ASPT is a full mission device which simulates the dual cockpit T-37B jet trainer. A state-of-the-art research simulator, ASPT is designed to assess the relationship between simulator fidelity and training concepts (Waag, Eddowes, Fuller, & Fuller, 1975). The basic ASPT device is intended to ". . .simulate ground operations, normal flight conditions, emergency flight conditions, aerobatic flight, formation flight, and post stall and spin in a high fidelity manner. The cockpits include faithful reproductions of in-cockpit sights, sounds, and control feel to the maximum extent allowable by the state-of-the-art and simulation realism versus functionality compromises." (Gum, Albery, & Basinger, 1975). A detailed technical description may be found in Bell (1974). The high fidelity ASPT with its automated performance measurement system was used to evaluate the training effectiveness of the LFS device.

T-4G Simulator. This USAF/HRL device is a modest fidelity, ground-based T-37 simulator with two degrees of motion and a narrow-angle, film-source visual system. It was developed to determine training effectiveness, using motion and a limited visual system in basic contact and instrument segments of the T-37 UPT program (Woodruff & Smith, 1974). In the present study, the T-4G simulator was used as a familiarization device for both student groups prior to their initial ASPT evaluation sortie. The modest fidelity of the

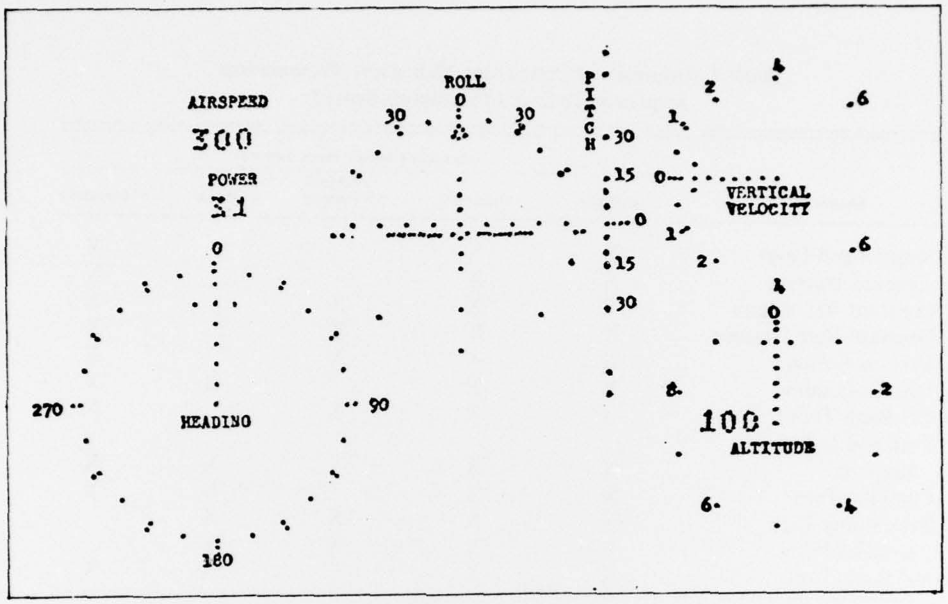

Figure 1. **Instrument display for LFS.**

T-4G, in terms of cockpit features, control feel, and engine sound, provides a realistic successive approximation to the high fidelity ASPT device.

T-4 Simulator. This device is the operational trainer for the 82nd Flying Training Wing, Air Training Command. It is a fixed-base, nonvisual system device that is used in the training of cockpit procedures, emergency procedures, navigation/communication, and instrument procedures for the T-37B aircraft. Control feel, cockpit features, and realistic engine sound provide a modest fidelity device. This simulator was used by both groups of students in the basic instrument phase of the UPT program.

Procedure

LFS Training. Both groups of student pilots were available two weeks prior to entry into UPT. Using the low fidelity simulation device (LFS), the seven members of the experimental group received 10 hours of basic instrument maneuver flying instruction over the 2-week period. Instructor Pilots (IPs) from Williams AFB selected the maneuver sequence and provided all flight instruction. Following a 15-minute familiarization free-flight, a fixed sequence of instrument maneuvers was presented to each of the experimental subjects. The sequence was selected in what was considered an ascending degree of difficulty and fixed across subjects. Preliminary observation indicated that the flight instruction became very demanding when continued beyond approximately 1½ hours. To control for unwanted fatigue effects, the scheduling of the subjects and the IPs was staggered. Consequently, the subjects received no more than approximately one hour of instruction in any 4-hour period.

Using the objective computer scoring performance metric described by Leshowitz and Nielson (1975), an *a priori* discrete performance level was selected as the criterion for advancement through the maneuvers, rather than a fixed number of trials per maneuver. The full performance metric consists of eight discrete performance levels: U (unsatisfactory), F– (fair minus), F (fair), F+ (fair plus), G– (good minus), G (good), G+ (good plus), and E (excellent). The criterion for proficiency advancement was arbitrarily selected to be two out of three successive performance levels equal to or greater than G– (good minus) with the additional requirement that the third performance level be no less than F (fair). The selected maneuvers, their presentation sequence, and the relevant computer scored parameters are summarized in Table 1.

T-4G Familiarization. Within a few days of entering the UPT program, both groups were required to fly an evaluation sortie in ASPT. To provide a graded approach to the high fidelity

Table 1. **Summary of Pretraining Maneuvers, Presentation Sequence, Relevant Parameters Scored**

	Relevant Parameters Scored				
Maneuver	Altitude	Velocity	Vertical Velocity	Bank	Heading
Straight-and-Level	X	X			X
Airspeed Increase	X	X			X
Constant Rate Climb	X	X	X		X
Constant Rate Descent	X	X	X		X
Vertical-S-Alpha	X	X	X		X
Turn-to-Heading	X	X		X	X
45° Bank Turn	X	X	X		X
Turn and Decrease Airspeed	X	X		X	X
Climbing Turn	X	X		X	X
Descending Turn	X	X	X	X	
Vertical-S-Delta	X	X	X	X	
60° Bank Turn	X	X		X	X

ASPT device, all members of both groups were first given a 30-minute familiarization ride in the T-4G simulator. An IP was present in the cockpit with each student and provided technical information and controls instruction. The T-4G time consisted of free-flight, together with demonstrated and practiced trials of each of the six evaluation maneuvers used in the study. Immediately following the T-4G familiarization ride, each student proceeded to his evaluation sortie in ASPT.

ASPT Evaluation Sortie. Upon first exposure to ASPT, each student was given a 10- to 15-minute free-flight period, during which time the IP pointed out simulator differences in control sensitivity, demonstrated the dynamics of the motion system, and, in general, acquainted the student with the operation of the system. At the completion of the free-flight period, the 6-maneuver evaluation sortie began. The test sortie required the students to fly two repetitions of the following six maneuvers: (a) straight-and-level; (b) airspeed increase; (c) turn-to-heading; (d) steep-turn (60° bank); (e) vertical-s-alpha; and (f) vertical-s-delta. The sequence was presented as described and was fixed across all subjects. At the completion of each discrete maneuver repetition, the cockpit IP provided a single performance rating for the maneuver. The scale used was the same 8-point scale used in the LFS training, i.e., U, F–, F+, G–, G, G+, and E. Automated Performance Measurement (APM) data were collected but were not used in the analysis, due to differences between the LFS and ASPT/APM scoring metrics. Following the completion of approximately one calendar month of T-4 simulator instrument training and prior to the basic contact flying phase of training, both groups were required to fly a second ASPT evaluation sortie identical in content to the first sortie. Identical dependent measures were taken.

T-4 Training. During the T-4 instrument phase of UPT training (i.e., the period between the two ASPT sorties) IP generated performance ratings were obtained for discrete trials of practiced maneuvers for both groups of students. An abbreviated 4-point scale of U, F, G, and E was used. Following the second ASPT evaluation sortie and for the first 10 presolo, dual-control sorties, actual flying performance measures were taken for a variety of maneuvers, using the same abbreviated UFGE scale. A letter grade was assigned to each repetition of the selected maneuvers, which included: (a) straight-and-level; (b) turn-to-heading; (c) change airspeed; (d) change airspeed (turning); (e) steep-turn (45° bank); and (f) steep-turn (60° bank).

III. RESULTS

Based on the previous acquisition curves, it was predicted that pretraining on the LFS device would transfer positively to ASPT and would result in superior performance of the experimental group over the control group for a number of selected maneuvers. The data from the first ASPT

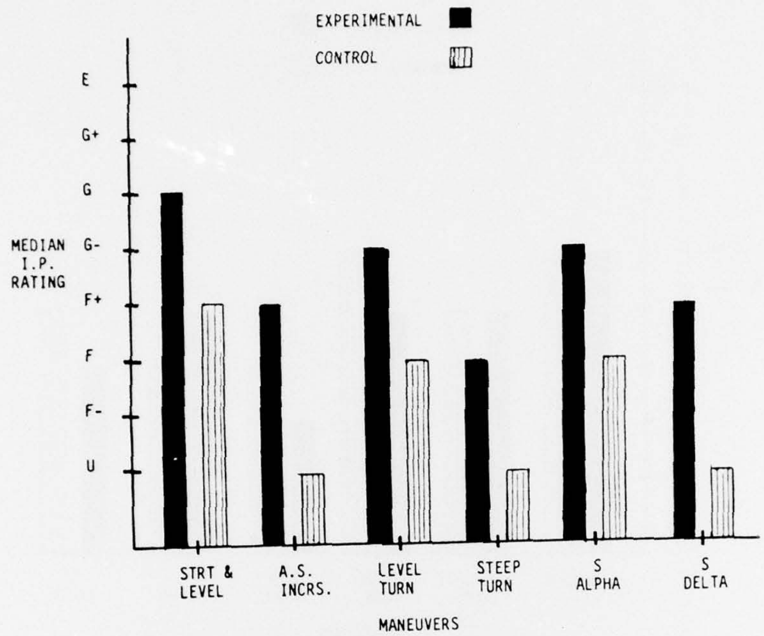

Figure 2. **Median IP ratings for first ASPT sortie.**

evaluation sortie, described in Figure 2 and analyzed via Mann-Whitney U Tests, indicate that the experimental group performed significantly superior to the control group across all maneuvers, U (6,6) = 3.00, $\underline{p}$ = .008.

The time course of the initial between-group differences was partly answered by obtaining performance data from the second ASPT evaluation sortie, approximately one month into the UPT program. By this time, both groups had received about 28 hours of academic procedures training and about 35 hours of basic part-task T-4 simulator instruction. The data, described in Figure 3 and subjected to Mann-Whitney U Tests indicate no significant difference between the two groups across maneuvers, U (6,6) = 15.50, $\underline{p}$ = .380.

In an attempt to understand the equal performance levels of the two groups in the second ASPT sortie, trials to criterion during T-4 simulator training were analyzed. A criterion similar to the LFS training criterion was used; that is, two out of three successive performance levels equal to or greater than G (good) with the additional requirement that the third performance level be no less than F (fair). If pretraining on the LFS device had a continuing, positive influence on flying training, then consistently fewer trials to criterion for the experimental group should be present during T-4 acquisition data. Figure 4 describes the comparison data between the two groups. Visual inspection of the data indicates a trend toward fewer number of trials to criterion for the experimental group over that of the control group. A 2 (Group) X 6 (Maneuver) split plot factorial analysis of variance indicates this trend reached only marginal significance, F(1,12) = 3.117, $\underline{p}$ = .10.

Additional performance data were taken following the second ASPT evaluation sortie as both student pilot groups entered the flying phase of training. It was hypothesized that the experimental group would demonstrate superior performance over that of the control group. This was not the case. Trials to criterion, determined in the same fashion as the T-4 data, are described in Figure 5. Visual inspection yields very little difference between the two groups across maneuvers. A 2 (Group) X 6 (Maneuver) split plot factorial analysis of variance indicates no significance between-group differences, F(1,12) = .121, $\underline{p}$ = .74.

IV. DISCUSSION

The present study investigated the transfer of training from a relatively inexpensive low fidelity simulation device, LFS, to a full mission high

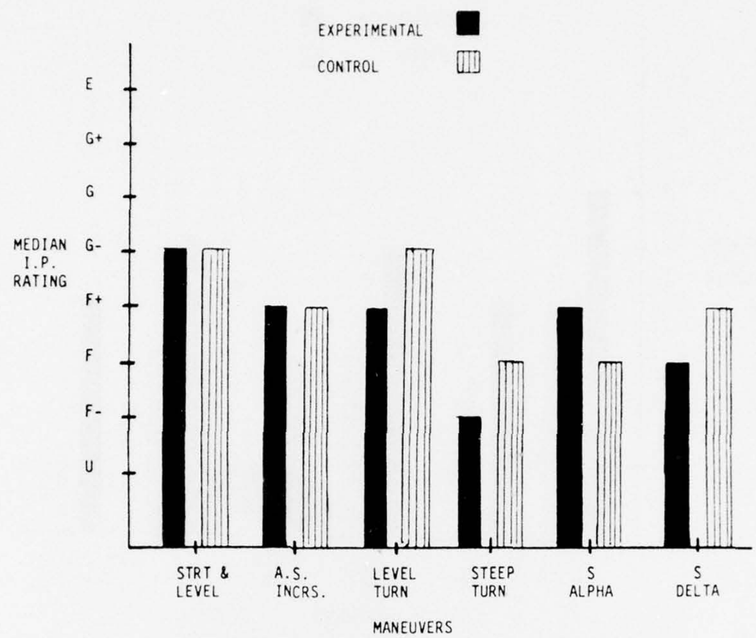

Figure 3. **Median IP ratings for second ASPT sortie.**

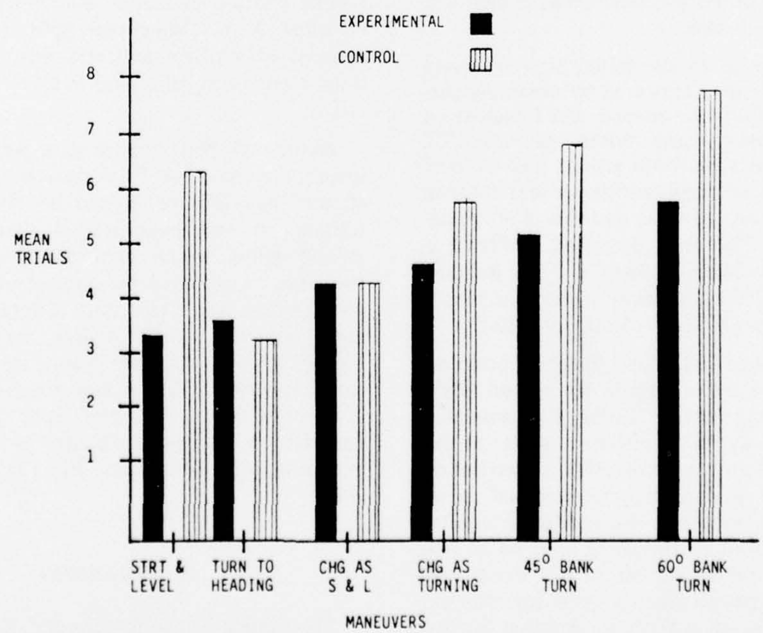

Figure 4. **Mean trials to criterion for T-4 instrument training.**

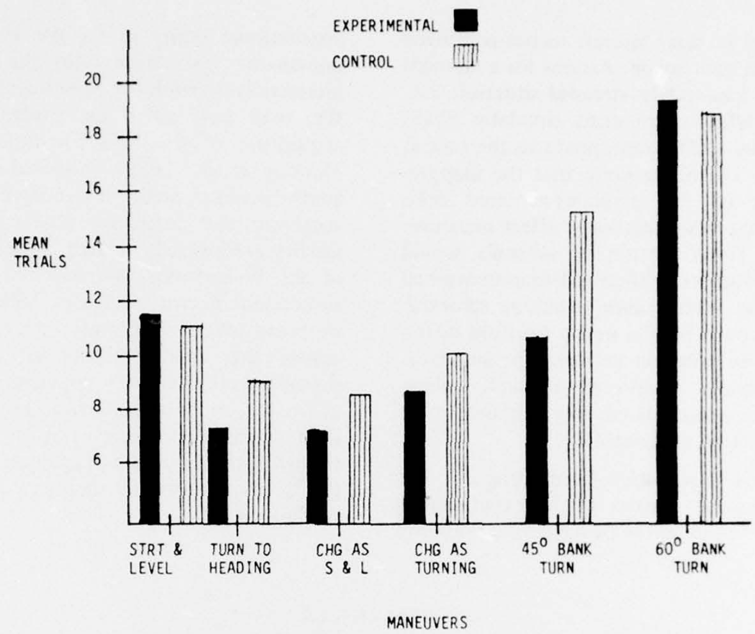

Figure 5. **Mean trials to criterion for T-37 basic contract training.**

fidelity state-of-the-art simulator, ASPT, and subsequently to the T-37B aircraft. the results indicate a considerable amount of positive transfer present at the onset of the UPT program. Initial performance differences, however, appeared to wash out following approximately one month of academic and part-task T-4 simulator instruction. Following the initial trials, there were no significant differences observed between the two groups of student pilots as they progressed through the basic instrument and basic contact flying phases of training. These observations were clearly contrary to our expectations. We had expected the experimental group to demonstrate superior performance well into the flying phase of training.

A variety of possible explanations are worthy of consideration. First, between-group differences in the first ASPT evaluation sortie clearly demonstrate positive transfer. The initial performance advantage of the experimental group did not, however, carry through the T-4 instrument and flying phase of training. One possible explanation is that members of the experimental group were at their performance ceiling as a result of 10 hours of LFS training. Assuming this observation is viable, then a comparison of the experimental group's performance ratings, between the first and second ASPT sortie, should show no improvement. Indeed, comparing the two ASPT sorties, the performance level of the experimental group in the second ASPT sortie is equal to or less than their performance level in the first sortie. In contrast, a between-sortie comparison for the control group indicates greater performance in the second sortie for all but one maneuver. These observations tend to support a ceiling effect explanation.

What is not immediately clear is why a considerably greater number of trials to criterion are required in the aircraft compared to the T-4 simulator for the same maneuvers. It is possible that while the T-4 simulator provides valuable cockpit procedures and early instrument cross-check practice, it may fail to provide realistic simulated practice for the more difficult maneuvers, such as the 60° bank steep turn. In fact, the same criticism can be leveled at the LFS device in that it does not faithfully reproduce the feel of the aircraft. Further research directly testing the training content of a variety of part and whole task maneuver skills is required to answer these questions.

Another possible explanation may be found in the differential stress factors involved in performing actual aircraft maneuvers versus simulator maneuvers. In fact, Krahenbuhl, Marett, and King (1977), in a recent study, have found evidence of increased stress in three aircraft sorties compared with a T-4 simulator sortie. Assume for a moment that during a moderately stressful situation, i.e., steep turn, earlier overlearned simulator skills, perhaps less than 100% appropriate to the task at hand, emerge. Further assume that the inappropriate aspects of the simulator-acquired skills interfere or otherwise negatively affect maneuver performance. These interfering subskills would have to be gradually modified and/or extinquished before criterion performance could be achieved. This could account for the nearly fourfold difference in trials to criterion between the simulator and the aircraft. Additional research, where induced stress is manipulated, may help determine the validity of these observations.

An alternate explanation accounting for the initial high positive transfer of the experimental group may be found in the demand effects and/or instructional ability of the IPs. For example, the one-on-one instruction, plus the close personal interaction between the experimental students and IPs, may have aided the student in the early acquisition of the LFS part-task skills. Indeed, Muckler et al. (1959), proposed that instructor ability is a large factor in training effectiveness. He suggested that instructor ability and simulation fidelity are inversely related. That is, as the ability of the IP increases, the required fidelity of the simulation device decreases. Should Muckler's proposed inverse relationship prove valid, it would appear that future transfer of training studies should investigate the interactive role of student, instructor, and training device(s) as a *system* rather than focusing exclusively on the simulator. Although a small number of subjects were utilized in this study, the results suggest a fruitful area for further research.

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