A SIMULATOR-BASED APPROACH TO TRAINING IN AERONAUTICAL DECISION MAKING

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FOREWORD

This report is submitted in fulfillment of the terms of the "Research Initiation Grant Program". This represents a full report on a study to optimize and validate an approach to pilot judgment training produced at the AFHRL, Williams AFB during the 1985 USAF-UES "Summer Faculty Research Project".

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Abstract

The effectiveness of a simulator-based approach to training pilot skills in risk assessment and decision making was evaluated in a sample of pilots enrolled in a university aviation science program. The 16 experimental group subjects received four hours of classroom instruction designed to enhance pilot judgment skills, followed by four simulated cross-country flights during which several critical in-flight events occurred. Subjects in the control group received classroom instruction in basic instrument flying, followed by simulator sessions emphasizing instrument flight. Measures of pilot judgment were obtained on all subjects before and after the training, and subjects in the experimental judgment-trained group performed significantly better on the post-training simulation than did control group subjects. The findings suggest that significant gains in pilot decision-making skill can be obtained through the use of the judgment training materials along with simulator practice. The implications of Air Force undergraduate pilot training are discussed.

Introduction

In the many critical work roles assigned to the modern Air Force pilot, there is often insufficient time or opportunity to acquire and perfect decision-making skills through experience alone. Although limited fuel supplies, equipment availability, and the high cost of missons have placed increasing constraints on flight time for training purposes, the military pilot of today must none-the-less be ready to perform with flawless precision on his very first operational assignment. In effect, he must develop good risk assessment and decision-making skills during a short period of training rather than over months or years of experience. Moreover, the high attrition rate among military personnel in recent years has further reduced the experience level of pilots throughout the Air Force (Allen, 1979): "Five years ago, 70 percent of U.S. Air Force fighter pilots had flown in actual combat; today, that same percentage has never seen combat (Knickerbocker, 1979, p. 2)".

The Air Force responded to this need by providing flight personnel with realistic experience in exercises such as Operation Red Flag, in which pilots fly in a hostile environment against other pilots who have been specially trained in aggressor tactics. But a unified methodology for fostering the acquisition of good judgment and decision-making skills has never been developed, and little research has been done to identify the most efficient environments for gaining such experience.

Statistics on both military and civilian aviation accidents clearly demonstrate that the majority of aircraft accidents are attributable to "pilot error". In most cases, this error is one of risk assessment and/or decision making -- pilot judgment. Although pilot judgment is a factor in every flight situation, it is of the greatest concern in those situations in which complex tasks are carried out under conditions of uncertainly, time pressure and stress (Brecke, 1982; Jensen, 1982). Pilot judgement has been defined as:

> ...the mental process by which the pilot recognizes analyzes, and evaluates information regarding himself, the aircraft, and the outside environment. The final step in the process is to make a decision pertaining to the safe operation of the aircraft and to implement the decision in a timely manner (Berlin, Gruber, Holmes, Jensen, Lau, Mills and O'Kane, 1982. p. 4.)

The need for a more flexible approach to pilot judgment training was recognized in the U.S. Air Force more than a decade ago with the implementation of the Situational Emergency Training (SET) program (Thorpe, Martin, Edwards, and Eddowes, 1976). Later, high-fidelity full-mission flight simulation, known as Line-Oriented Flight Training (LOFT), was employed for training pilots who serve in multi-crew environments (Lauber and Foushee, 1981). Cockpit Resource Management (CRM) is another model for aircrew training which was built upon the basic LOFT paradigm. CRM focuses on decision-making and crew coordination (Cooper, White, and Lauber, 1979), and has now become a major component in the training programs for air-carrier and military transport personnel.

During this period too, the utility of special training programs to improve civil pilot judgment was demonstrated in a series of carefully planned investigations. Following an FAA-supported study which concluded that faulty pilot decisional activities were involved in 35% of all fatal general aviation accidents and in 52% of all non-fatal accidents, researchers at Embry-Riddle Aeronautical University (ERAU) produced prototype judgment-training materials for student and instructor pilots. Using an observation flight protocol to measure pilot judgment, the ERAU group demonstrated that these materials could be effective in improving pilot decision making (Berlin et. al., 1982).

An independent evaluation of these training materials was subsequently carried out in Canada using a sample of civilian Air Cadets. In this study too, subjects who received judgment training did significantly better on the observation flight than did control subjects (Buch and Diehl, 1984). While these studies employed classroom instruction in the judgment-training concepts along with coordinated in-flight activities, a second Canadian study demonstrated that the use of self-paced student manuals alone could also result in a significant improvement in observation flight performance (Buch and Diehl, 1983).

A recent field study conducted at FBO flight schools used subjects more representative of the general population of student pilots (Diehl and Lester, 1986). In this experiment too, these subjects who received the judgment training did significantly better on the observation flight than did control group subjects.

However, with the sole exception of the one Canadian study which used only the self-paced student manual, all of these investigations have used a coordinated series of in-flight exercises to complement the classroom teaching of risk assessment and decision making. Given the high cost of actual flight time, particularly in high-performance military aircraft, it was felt that an alternative approach was needed. The present study was therefore concerned with the use of a flight simulator in the training of pilot decision-making skills. The intent was to model, as faithfully as possible, the simulator-training environment provided within the Air Force's Undergraduate Pilot Training (UPT) program.

METHOD

Subjects

The subjects were randomly selected from among Aeronautical Science students enrolled in a Principles of Flight Instruction course at Embry-Riddle Aeronautical University. At the outset of the experiment, all subjects held a Private Pilot certificate with an Airplane Single Engine Land rating. Three control group subjects and six subjects in the experimental group also held multi-engine ratings. Subjects were randomly assigned to either the experimental or control group. There was no significant different between the experimental and control group either in age (t = 0.93, df = 27) or flight experience (t = 1.06, df = 27). The number of subjects in each group, their mean age, and mean flight experience is shown in Table 1.

Procedure

The experimental design compared the performance of 16 pilots who received classroom instruction and simulator training in aeronautical decision making with that of 13 subjects trained under a control condition which focussed on basic instrument flying. Before and after this training, subjects in both groups were evaluated on simulated cross-country VFR flights. All simulators were conducted in the generically configured cockpit of a Singer-Link GAT-1 two axis-simulator with movable pedestal. The simulator provided no visual depiction.

Before beginning their training, subjects in the experimental group completed a ten-item self-assessment pilot attitude inventory. This instrument is a modified form of the "Pilot Decisional Attribute Questionnaire" and yields scores which presumably reflect the relative strength of each of the five hazardous thought patterns. The four hours of classroom instruction were based on the Aeronautical Decision Making for Instrument Pilots text (Jensen and Adrion, 1984) and emphasized the hazardous thoughts. This was followed by four simulator training sessions conducted by full-time ERAU flight instructors who had volunteered for the project. Each instructor had received eight hours of special training on the hazardous thought patterns and on the procedures to be used during the simulator training. The simulators were all VFR cross-country flights during which several critical events occurred. The instructors selected one of four possible routes of flight for each session. No flight scenario or critical event was used twice. The specific events used for each subject were selected by the instructors on an ad hoc basis from among those listed in Table 2. The duration and complexity of the flights increased systematically over the course of the four simulations as shown in Table 3.

Subjects in the control group received four hours of classroom instruction on basic instrument flying from the same ERAU faculty member who taught aeronautical decision making to the experimental group. They also participated in four instrument flight simulator training sessions. These simulations followed the same time schedule and were conducted by the same flight instructors who conducted the simulator training for the experimental group.

The performance of subjects in both groups was evaluated on flight simulations administered before and after the training. Before beginning these pretest and posttest simulations, each subject was reminded that he was to act as the pilot-in-command of a night cross-country VFR flight which was to be conducted as a Line-Oriented Flight Training (LOFT) exercise, "exactly like an actual flight". No information other than the route of flight was provided unless specifically requested by the subject.

During the pretest flight, each subject pilot experienced three critical events in sequence: 1) the failure of all navigation reception while outbound from the departure airport VOR: 2) changing weather conditions which resulted in both the departure and destination fields dropping below VFR minimums; and 3) the failure of all communication receivers. The post test flight was similar to the pretest, but included three critical events which had not previously been used in the training with that particular subject. In addition, the noise level and turbulence was increased progressively during this flight in order to increase pilot stress.

Two performance measures were obtained on the pretest and posttest flights. At the time of the flight itself, the experimenter completed a ten-item checklist of activities related to the flight. These items appear in Table 4. This procedure yielded a score which could range from zero to ten for each subject. A second measure of performance was obtained by having each subject's record from both the pretest and posttest flights independently evaluated by five raters who were not involved in the study and were unaware of the details of the experimental design. All raters were Certified Flight Instructors and Designated Examiners. Three held Airline Transport Pilot certificates and two held Commercial Pilot Certificates. The raters had no way of knowing whether a record came from a subject in the experimental or control group, or whether the flight represented a pretest or posttest simulation.

Using both a graphic record of the flight and the checklist described above, raters assigned a score ranging from -5 to +5 to each flight. A rating of +5 indicated the "best possible judgment", while a rating of -5 was applied to the "worst possible judgment". Raters were instructed to base the ratings on their expectations for an average general aviation pilot with 200 hours of flight experience. They were specifically cautioned to avoid evaluating the "skill" of the pilot.

RESULTS & DISCUSSION

The scores assigned by the five raters were summated by computing the median score for each subject's pretest and posttest flight. These median ratings were compared to the checklist scores assigned by the experimenter at the time of the flight, and a high level of agreement was noted. Pretest checklist scores correlated $r = +0.64$ with median pretest ratings, and posttest check list scores correlated $r = +0.86$ with median posttest ratings. This suggest that both measures of the dependent variable reflect the same dimension, presumably that of judgment, risk assessment and decision-making ability.

The effects of the special training were examined using both the checklist scores and the median flight ratings as indices of change. Random assignment was effective in equating the experimental and control groups at the outset of the experiment. There was no significant difference between the experimental and control group in either pretest checklist scores (t = 0.43, df = 27) or in ratings of the pretest flight (t = 0.38, df = 27). This data is shown in Table 5.

An examination of the posttest flight records revealed a highly significant difference between the experimental and control group on both measures of the dependent variable. Both checklist scores (t = 8.41, df = 27) and flight ratings (t = 4.57, df = 27) indicated that the experimental group performed significantly better on the posttest than did the control group. This data is shown in Table 6. The pretest and posttest checklist data for both groups is depicted graphically in Figure 1. The flight ratings data are shown in Figure 2.

A somewhat more sensitive measure of change is provided by using each subject as their own control and examining the changes in the dependent variable measure from pretest to posttest. This change score reflects a highly significant difference between the experimental and control group with respect to both checklist scores (t = 7.39, df = 27) and flight ratings (t = 5.14, df = 27). Compared with the control group, the experimental group evidenced a significantly greater amount of change on both variables following training. This data is shown in Table 7 and illustrated graphically in Figure 3.

IMPLICATIONS & CONCLUSIONS

The results provide an exceptionally clear demonstration of the effectiveness of the simulator-based judgment training program. Subjects who received four hours of classroom instruction in risk assessment and decision making followed by four instructional simulations in which they experienced several critical in-flight events performed significantly better than did control group subjects when later evaluated on their handling of such events. This suggests that effective judgment training can be accomplished without reliance upon actual aircraft flight time.

Moreover, the study also demonstrated that the judgment training program can be used effectively with pilots who are beyond the ab initio stages of their training. In contrast to previous investigations, all of the subjects in the present study were well beyond the private pilot certificate when they began their training. The manual used herein was designed for students who are beginning their instrument training, and is more appropriate to the Air Force UPT Program than earlier versions of civil pilot judgment training materials.

Thus, the authors recommend that the judgment training model tested in this study, along with classroom instruction and flight simulation training in the use of good risk-assessment and decision-making skills in the handling of critical in-flight events, be incorporated into the Air force UPT Program.

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Table 1
Sample

	Experimental Group	Control Group
Number of Subjects	16	13
Age (years)	20.9	21.2
Flight Experience (hours)	197.3	203.0

Table 2
Critical In-Flight Events

A. destination airport closed due to an accident
B. severe turbulence
C. drop in oil pressure; no change in oil temperature
D. departure field goes IMC
E. suction failure; AI and HI inoperative
F. loss of navigation station signal
G. loss of two-way radio communication
H. pitot-static system failure
I. partial loss of engine power
J. radar contact lost during radar vectoring
K. low fuel
L. flight vectored into restricted area
M. 30 minute delay for landing upon arrival at destination airport
N. PCL lighting inoperative upon arrival at destination airport
O. pilot given vectors opposite the desired direction of flight
P. pilot cleared to take off immediately behind B-727
Q. pilot advised FSS does not have copy of flight plan
R. scattered cloud deck at cruising altitude
S. smoke or burning odor in cockpit

Table 3
Training Simulations for Experimental Group

Flight No.	Duration (mins)	Critical Events
1	15	2
2	30	4
3	45	6
4	60	8

Table 4
Checklist of Pilot Decisional Activities

1. requested preflight weather briefing
2. activated flight plan
3. checked fuel
4. requested radar advisories
5. checked weather enroute
6. accurately computed ETA for first intersection
7. activated flight plan to alternate field
8. initiated DR procedures following equipment failure
9. elected cruise altitude above MEA
10. requested assistance and/or confessed problems

Table 5
Pretest Checklist Scores and Flight Ratings

	Experimental Group (N = 16)		Control Group (N = 13)	
	Mean	S.D.	Mean	S.D.
Checklist Score	4.06	1.53	4.31	1.49
Flight Rating	- 2.75	1.48	-2.92	0.76

Table 6
Posttest Checklist Scores and Flight Ratings

	Experimental Group (N = 16)		Control Group (N = 13)	
	Mean	S.D.	Mean	S.D.
Checklist Score	8.63	1.50	3.46	1.81
Flight Rating	+ 1.63	2.80	- 2.54	1.90

Table 7
Changes in Checklist Scores and Flight Ratings

	Experimental Group (N = 16)		Control Group (N = 13)	
	Mean	S.D.	Mean	S.D.
Checklist Score	+ 4.56	1.86	- 0.85	2.08
Flight Rating	+ 4.38	2.42	+ 0.39	1.56

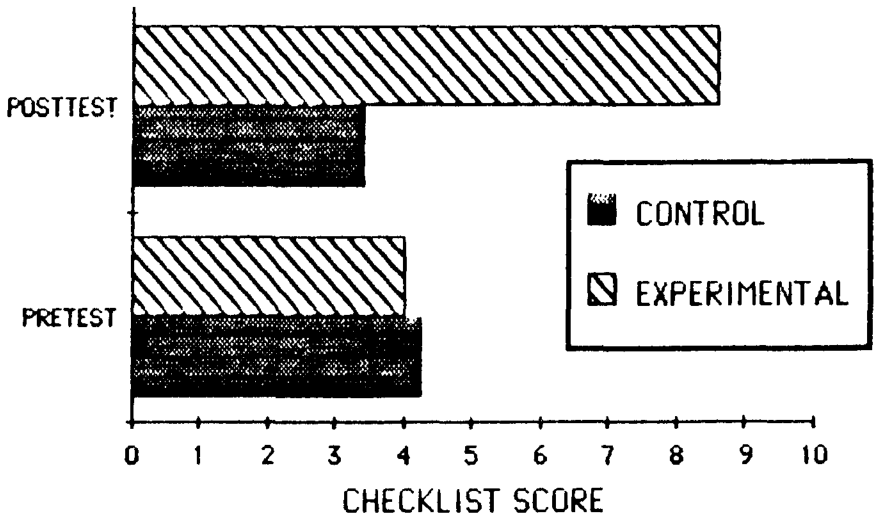

Figure 1. Pretest and posttest checklist scores.

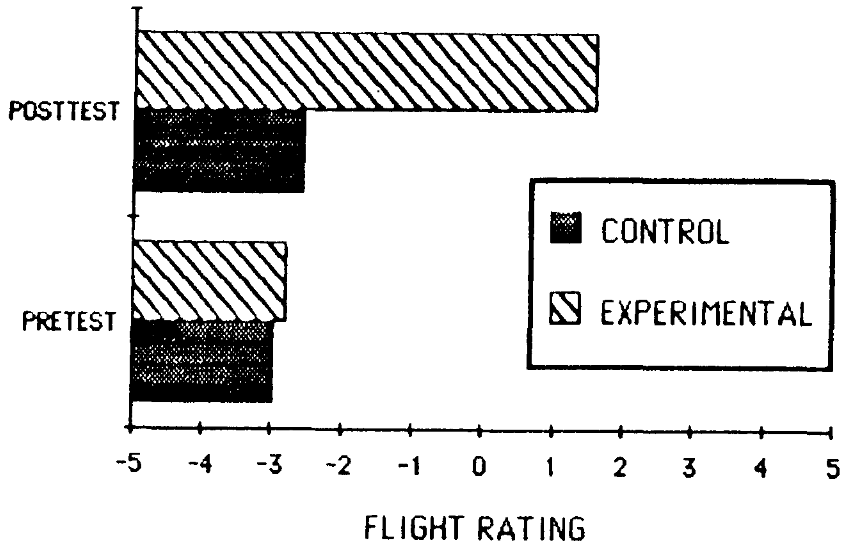

Figure 2. Pretest and posttest flight ratings.

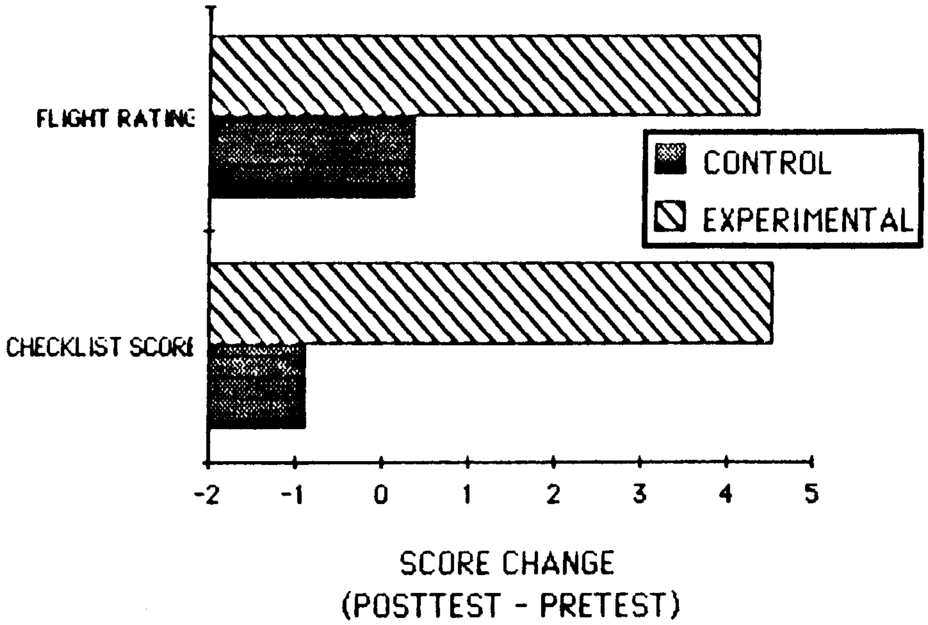

Figure 3. Changes in checklist scores and flight ratings following training.

Appendix A

Judgment Training Syllabus

Each lesson of the Judgment Training Syllabus which follows sets forth a unit of classroom instruction or a unit of simulator instruction. Neither the time nor the number of periods to be devoted to each lesson is specified - only recommended. The test project devoted 4 hours of classroom instruction to Lesson 1 and 2 hours 30 minutes (4 sessions) to Lesson 2.

Each lesson includes an Objective, Content and Completion Standard.

Lesson No. 1

(Recommend 4 hours of instruction)

Objective:

Traditional pilot training emphasizes the pilots knowledge about the aircraft and the flight environment. Judgment training focuses on the pilots additional need for accurate and complete self-knowledge. The success of this training course thus greatly depends upon teaching the student to think more carefully and throughly about his attitudes and behaviors.

Upon completion of this lesson and when presented with a series of true flying situations the pilot will be able to identify hazardous thought patterns and substitute thoughts which promote good judgment.

Additionally he will define the factors causing stress, explain the effects of stress on performance and outline strategies for overcoming high stress which reduces judgment making abilities.

Content: (Student should read and complete the entire "Aeronautical Decision Making" Manual during this lesson.)

1. Pilot Decisional Attitude Questionnaire (PDAQ)
2. Aeronautical Decision Making
    a. The pilot judgment problem
    b. Relationship of judgment to training
    c. Attitudes in decision making
    d. The poor judgment chain
    e. Antidotes for hazardous thoughts
3. Influences and resolution of stress
    a. Define stress
    b. Factors causing stress and effects of stress
    c. Coping with stress

Completion Standard:

The lesson will have been successfully completed when the student can accurately, 100 percent of the time, identify the hazardous thought contained in five given flight situations and apply the appropriate antidote. Additionally, the student will formulate a strategy for coping with stress consistent with the techniques outlined in the "Aeronautical Decision Making for Air Force Pilots" manual.

Lesson No. 2

(Recommend 5 simulated flights - including the evaluation flight)

Objective:

When given a solo cross country flight in the simulator, the pilot will demonstrate stress coping techniques and good decision making strategies for dealing with preprogram critical in-flight events.

Content:

This lesson should be completed using a series of simulated flights as follows:

Flight No. 1 - 15 min. - 2 critical events

Flight No. 2 - 30 min. - 4 critical events

Flight No. 3 - 45 min. - 6 critical events

Flight No. 4 - 60 min. - 8 critical events

Flight No. 5 - 60 min. - 8 critical events

The flights and critical in-flight events should be selected from a prepared Teaching Outline (see Appendix B), and once used should not be repeated until Flight No. 5. Flight No. 5 should involve a combination of events <u>different</u> from those used in Flight No. 4. Each flight should be conducted as a full-mission simulation (FMS) which lies at the high end of the range of fidelity associated with mission-oriented simulation (MOS).

1. Preflight discussion.
    a. Provide departure point, route and destination for the planned flight.
    b. Pilot should use actual data for that day in planning the flight.

2. Simulated flight.
    a. Critical in-flight events as selected by the instructor.

3. Post flight critique.
    a. Emphasize application of knowledge and skills acquired in Lesson No. 1.

Completion Standard:

The lesson will have been successfully completed when the pilot can recognize the situation presented as one inviting poor judgment and applies the appropriate techniques as presented in Lesson No. 1.

Appendix B

Teaching Outline

(The Flight and Critical In-Flight events listed here are specific to the test project and will need to be changed for use in the Air Force simulator).

NAME_______________________

Indicate the lesson, flight plan and critical events below

LESSON: (Circle one of the following)

1 2 3 4 5

****

FLIGHT PLAN (Circle the appropriate number to the left of the plan used)

1. Plan a VFR cross country; SEA to Gain County.
2. Plan a NIGHT VFR cross country; Green Airpark to Waycross County.
3. Plan VFR cross country; Gain County to Newton to Green Airpark.
4. Plan VFR cross country; SEA to Zang to Moyer Memorial.
5. Plan VFR cross country; SEA to Newton to Green Airpark.

****

CRITICAL IN-FLIGHT EVENT (Circle the letter to the left of each event used)

A. Upon opening flight plan student is told destination airport closed because of an accident.
B. Severe turbulence.
C. Drop in oil pressure; no change in oil temperature.
D. Departure field goes IMC.
E. Suction failure; AI and HI.
F. Loss of navigation station signal.
G. Loss of two way radio communication.
H. Pitot - Static system failure.
I. Partial loss of engine power.
J. Radar vectors for spacing and radar contact lost before intercept vector given.
K. Low fuel situation.
L. Vector into restricted area.
M. Pilot informed of a 30 minute delay for landing upon arrival at destination.
N. Upon arrival at destination pilot is told PCL lighting inoperative.
O. Vectors opposite the desired direction of flight.
P. Cleared to take off immediately behind a B-727.
Q. Told FSS does not find copy of FAA flight plan.
R. Student told to increase speed to arrive at destination 15 minutes early (low fuel state).
S. Student told that scattered cloud deck is at cruising altitude (reported ceiling is 3000 feet higher).
T. Student informed of smoke or burning odor in the cockpit.

****

Indicate Hazardous Attitudes Observed: ...Invulnerability; ....Macho; ....Impulsivity; ....Resignation; .... Anti-Authority