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SYSTEM PERFORMANCE, ERROR RATES, AND TRAINING TIME FOR RECENT FAA ACADEMY NONRADAR GRADUATES, COMMUNITY PERSONS, AND HANDICAPPED PERSONS ON THE RADAR TRAINING FACILITY PILOT POSITION

James O. Boone
Jo Ann Steen
Linda K. Van Buskirk
Civil Aeromedical Institute
Federal Aviation Administration
Oklahoma City, Oklahoma

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7. Author(s)
James O. Boone, Jo Ann Steen, and Linda K. Van Buskirk

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16. Abstract
In May 1980 the Federal Aviation Administration completed construction of a Radar Training Facility (RTF) in Oklahoma City. The primary objective of the RTF is to closely duplicate the specialized operational environment existing at automated Terminal and En Route facilities as well as to have the capability of synthesizing a wide variety of air traffic control situations. Corresponding to each radar training sector, there is a manual controller position, a ghost position, and three pilot positions. The ghost positions serve as the adjacent sectors to the radar position, while persons at the pilot positions control the flight of the aircraft simulated at the radar positions.

Errors at the pilot position confound the scoring procedure for evaluating the performance of the trainee in the radar position. This study was designed to determine the expected error rates, what inputs result in the most errors, how long it takes to train pilots to proficiency, and who should/could operate the pilot positions. With respect to the latter, error rates and training time were compared for three groups; namely, air traffic control specialist trainees, community persons, and handicapped persons.

The results of the study indicate that all three groups can learn to operate the pilot position within a reasonable length of time with an acceptable error rate. A recommendation is made to employ handicapped and community persons at the pilot position in order to maintain a stable, competent group of RTF pilots.

17. Key Words
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I. Introduction.

A. Background. The original simulators used in air traffic control (ATC) training were "patches" added to the operational field systems of the NAS-A and ARTS-III.* The patches permitted flexible training at designated positions without interfering significantly with the operational positions. These prototype simulators resulted in at least two major notions related to using simulation for radar training. First, the value of computer-driven simulation for training purposes was firmly established. Second, several problems associated with using operational field systems in a training mode were identified. The Institute for Defense Analysis (IDA) study on the training of air traffic controllers discussed some of these problems and suggested that a standardized computer-driven program should be established by the Federal Aviation Administration (FAA) to provide basic radar training. The IDA study further suggested that the radar training should be pass/fail to identify those persons who did not demonstrate the potential to perform proficiently in a radar environment (2).

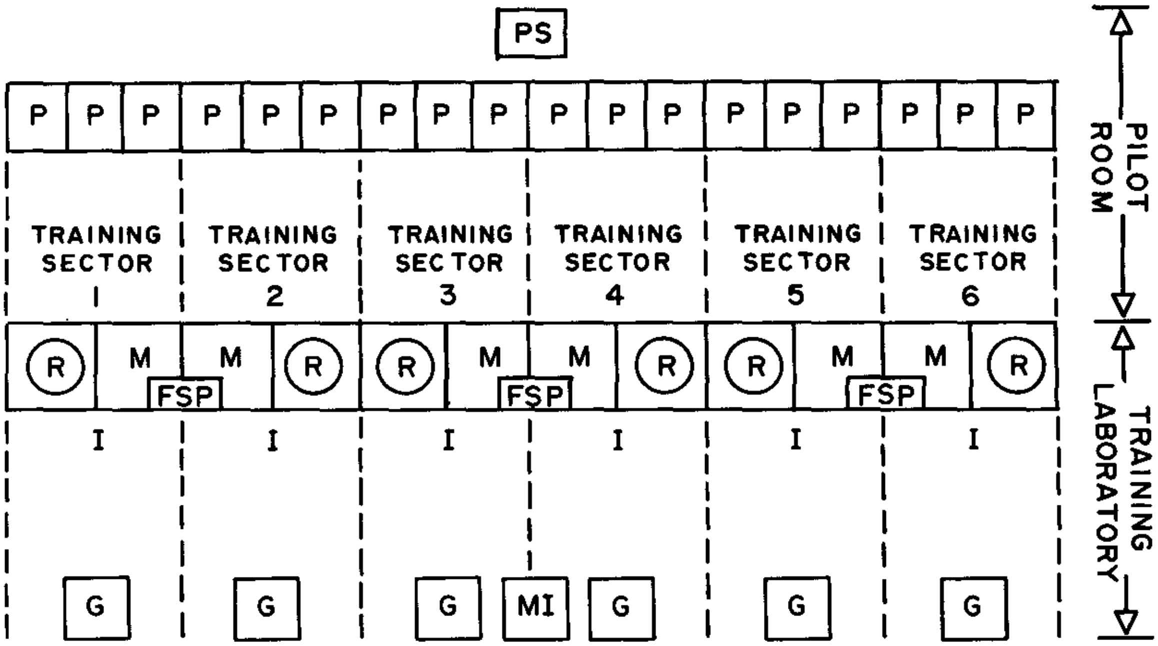
In July 1976 engineering requirements were completed by the FAA for a radar training system (1). During that same month, the FAA Administrator approved the procurement and construction of the Radar Training Facility (RTF) to be located at the FAA Academy in Oklahoma City, Oklahoma.

In October 1977 the FAA completed a program implementation plan that outlined the development and implementation of the RTF. The contract for the development of the computer-driven simulator training system was awarded to Logicon, Tactical and Training System Division, San Diego, California, in January 1978. Groundbreaking for the construction of the new RTF at the FAA Academy was held on December 22, 1977.

B. RTF Training System and Laboratory Configuration. The primary objective of the RTF, as stated in the engineering requirements, is to closely duplicate the specialized operational environment existing at automated Terminal and En Route facilities as well as have the capability of synthesizing a wide variety of air traffic control situations. These situations would be based on a reference data base created through scenario programs with a full range of control necessary to establish a realistic simulation of actual aircraft traffic under a variety of conditions.

To accomplish this objective, Logicon proposed that four independent laboratories be constructed. Figure 1 describes how the laboratories are configured.

*Computer systems employed in En Route and Terminal air traffic control, respectively.



P - Pilot Console
G - Ghost Console
R - Radar Training Console
M - Manual Controller Trainee Position
En Route "D" Controller or
Terminal "HO" Controller

MI - Master Instructor Position
PS - Pilot Supervisor Station
I - Instructor Station
FSP - Flight Strip Printer

FIGURE 1. Typical laboratory

Corresponding to each radar training sector, there is a manual controller position, a ghost position, and three pilot positions. The ghost positions will serve as the adjacent sectors to the radar positions or other facilities, while the pilot positions will control the flight of the aircraft simulated at the radar position. Each of the four laboratories, two En Route and two Terminal, can train six radar control students simultaneously. There is an instructor station at each of the radar positions and a master instructor station and system monitor station in each of the four laboratories. Table 1 summarizes the totals of the various positions in the RTF.

Table 1. RTF Positions

24	Radar Positions
24	Data Handler Positions
72	Pilot Positions
24	Ghost Positions
4	Master Instructor Stations
4	System Monitor Stations
24	Instructor Stations

Figure 2 describes the system configuration for operating the positions and stations in each laboratory. The training sectors are controlled by a Digital Equipment Corporation (DEC) PDP 11/60 computer with a PDP 11/34 computer serving as an interface between the PDP 11/60 and the operating positions.

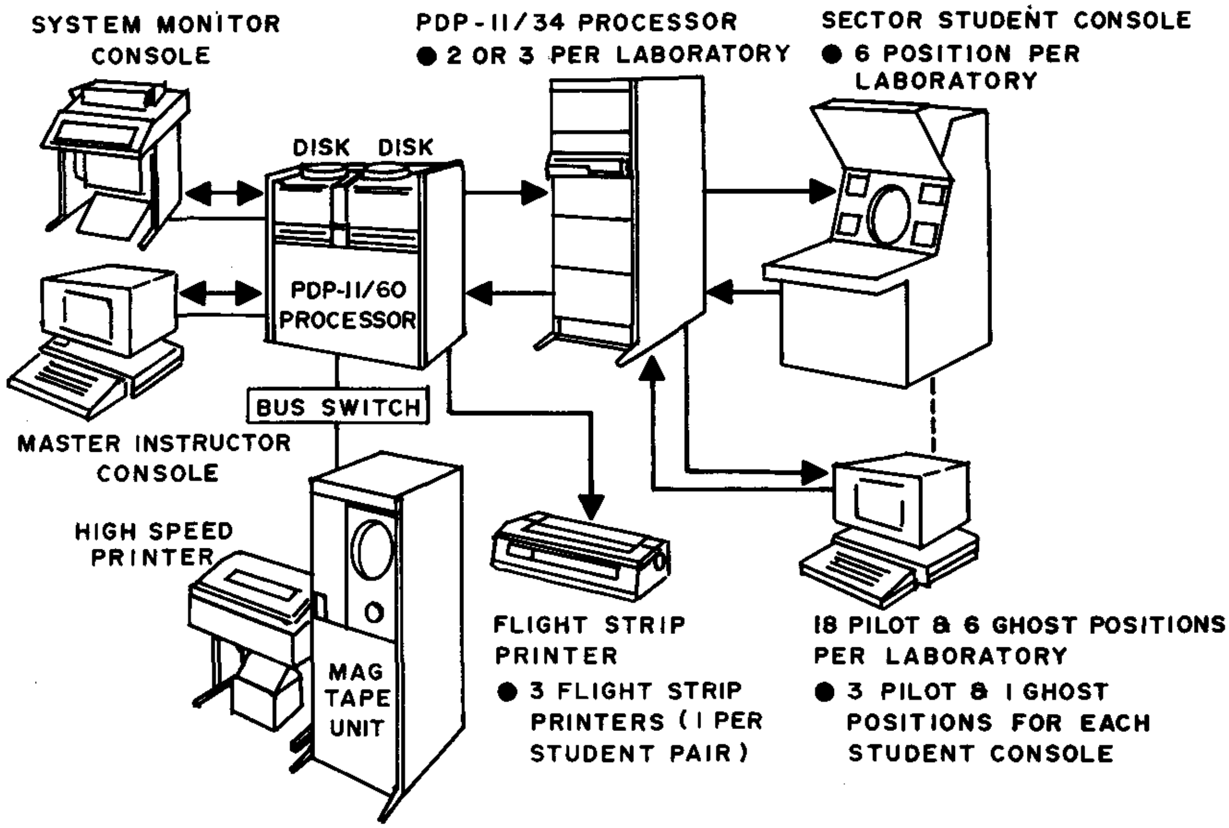


FIGURE 2. System configuration.

The training process involves three sequential systems of operation: SCENARIO GENERATION ---→ REAL-TIME TRAINING ---→ PERFORMANCE MEASUREMENT.

Scenario generation, illustrated in Figure 3, is the non-real-time process of building exercises and evaluation problems for the system.

Aircraft characteristics, flight plans, and other essential information of this type are stored in the Universal Data Files (UDF). The exercise is built by first selectively retrieving intermediate files and then creating other intermediate data files from the universal data base through the scenario management program.

The real-time component, illustrated in Figure 4, utilizes the scenario management files to generate the actual radar simulation exercise. The

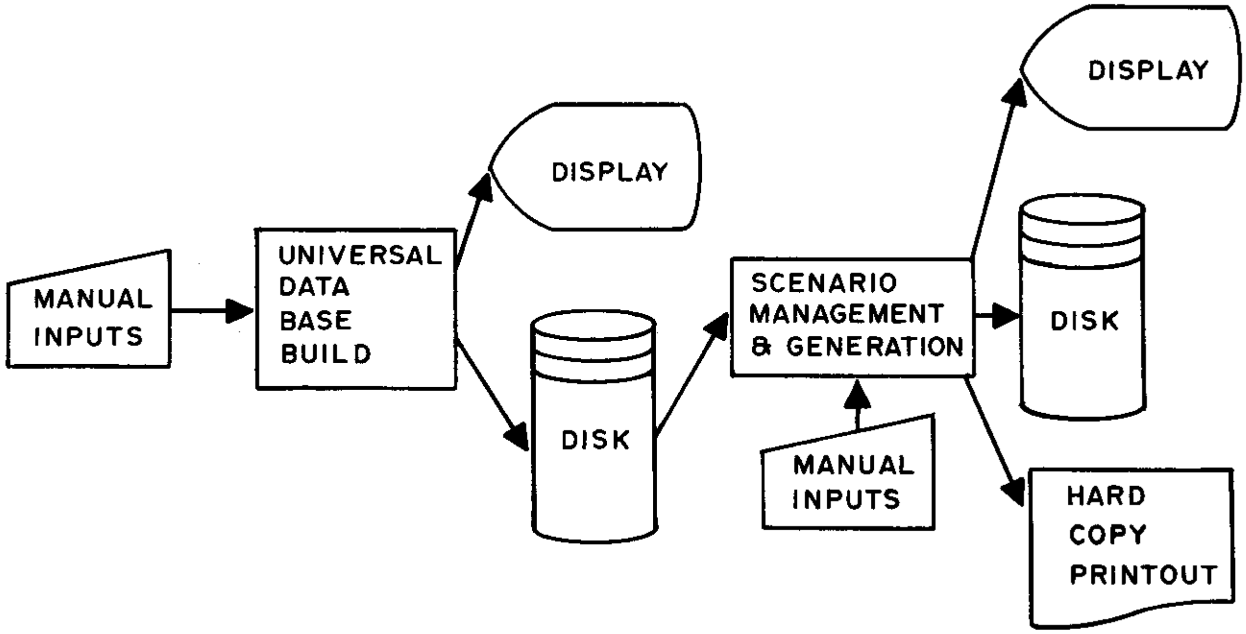


FIGURE 3. Scenario generation.

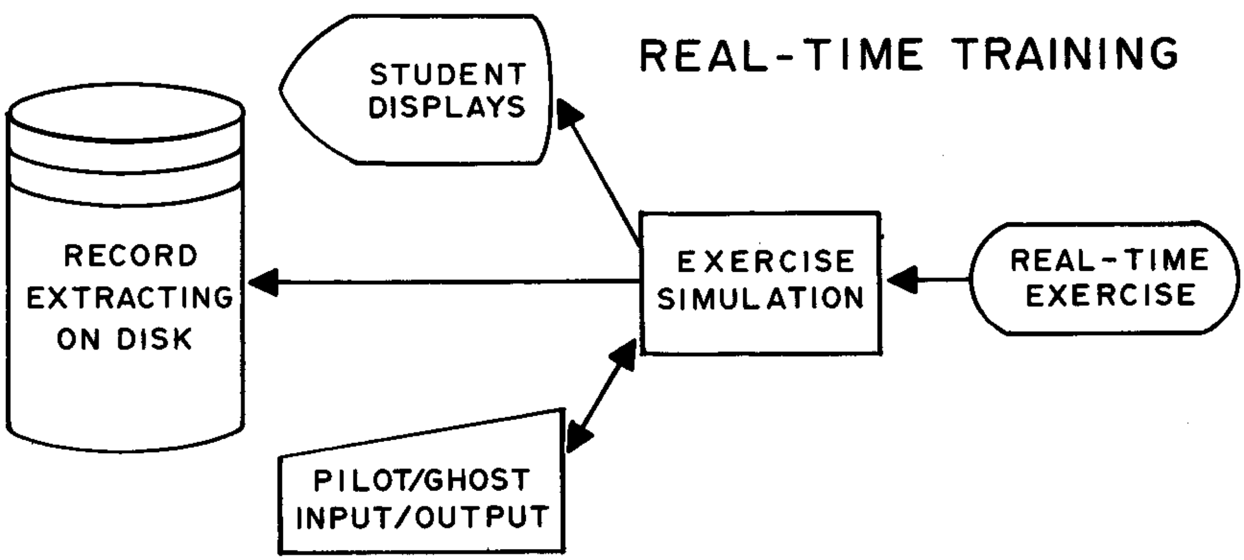


FIGURE 4. Real-time training.

real-time component drives the display at the radar position. Aircraft movement is controlled through the pilot and ghost positions according to the instructions those positions receive from the controller trainee or in some cases forms a scenario prompt that appears on the pilot or ghost cathode-ray tube (CRT) at those responsive positions. All actions taken during the operation of the real-time training exercise are recorded.

At completion of the exercise, the computer will analyze the recorded actions to determine violations of separation standards and other pertinent information, such as delay times, in order to evaluate the student's ability to move air traffic "safely and expeditiously." The process of student performance measurement is illustrated in Figure 5.

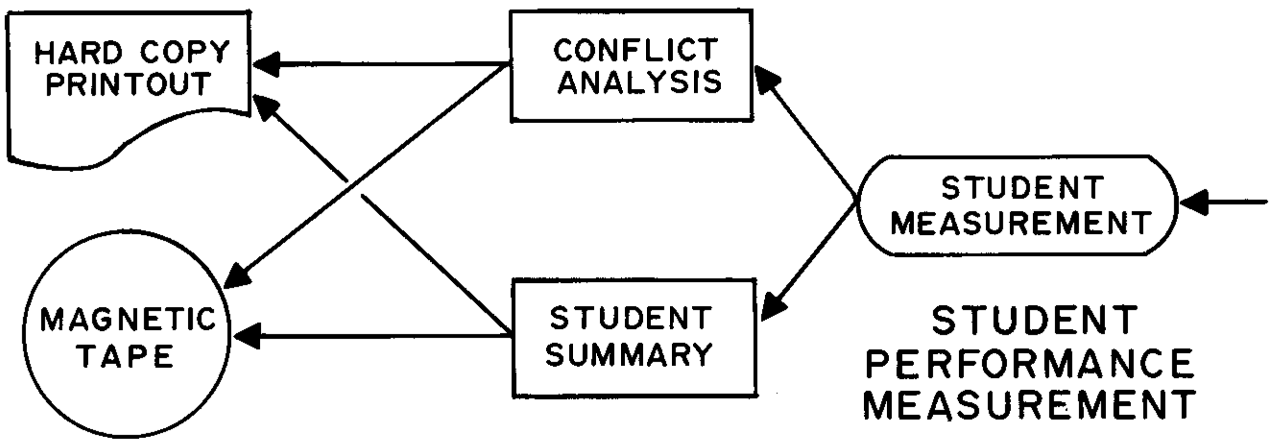


FIGURE 5. Student performance measurement.

C. Purpose of This Study. This study is concerned with the operation of the pilot position in the real-time training program. The pilot position console, a modified version of the Hazeltine Modular One Terminal, consists of a tabular CRT display with associated controls and data entry devices (see Figure 6).

Three pilot positions support each radar position. The pilot positions are used to maneuver the aircraft targets displayed on the radar CRT. The data entry and readout capabilities of the pilot position permit rapid entries and changes to the aircraft flight status according to the instructions received from the radar air traffic control trainee.

It is apparent from Figure 4, which describes the real-time training system, that the accuracy of the inputs (responses) from the pilot position affect the performance score of the trainee who is in the radar position. Suppose, for example, that an aircraft is instructed by the trainee controller to turn to a 60° heading but the pilot inadvertently turns to a 260° heading. An error such as this would certainly confound the scoring procedure for evaluating the performance of the trainee in the radar position. The first questions that arose in this study were related to the expected accuracy of the inputs from the pilot position: What are the expected error rates? What inputs will result in the most errors? What inputs should be emphasized more in pilot training? Should the keyboard arrangement be modified to aid in accuracy?

Another unknown parameter was training time. The schedule of laboratory use must include an instructional component for the pilot position. The question of how long it takes to train to proficiency needed to be answered.

A third important topic of inquiry in the study was the feasibility of using the RTF computer facilities for computer-assisted programed instruction for pilot training. This required the creation and evaluation of a prototype training system, and an evaluation of the feasibility of modifying the RTF training equipment for use in pilot training.

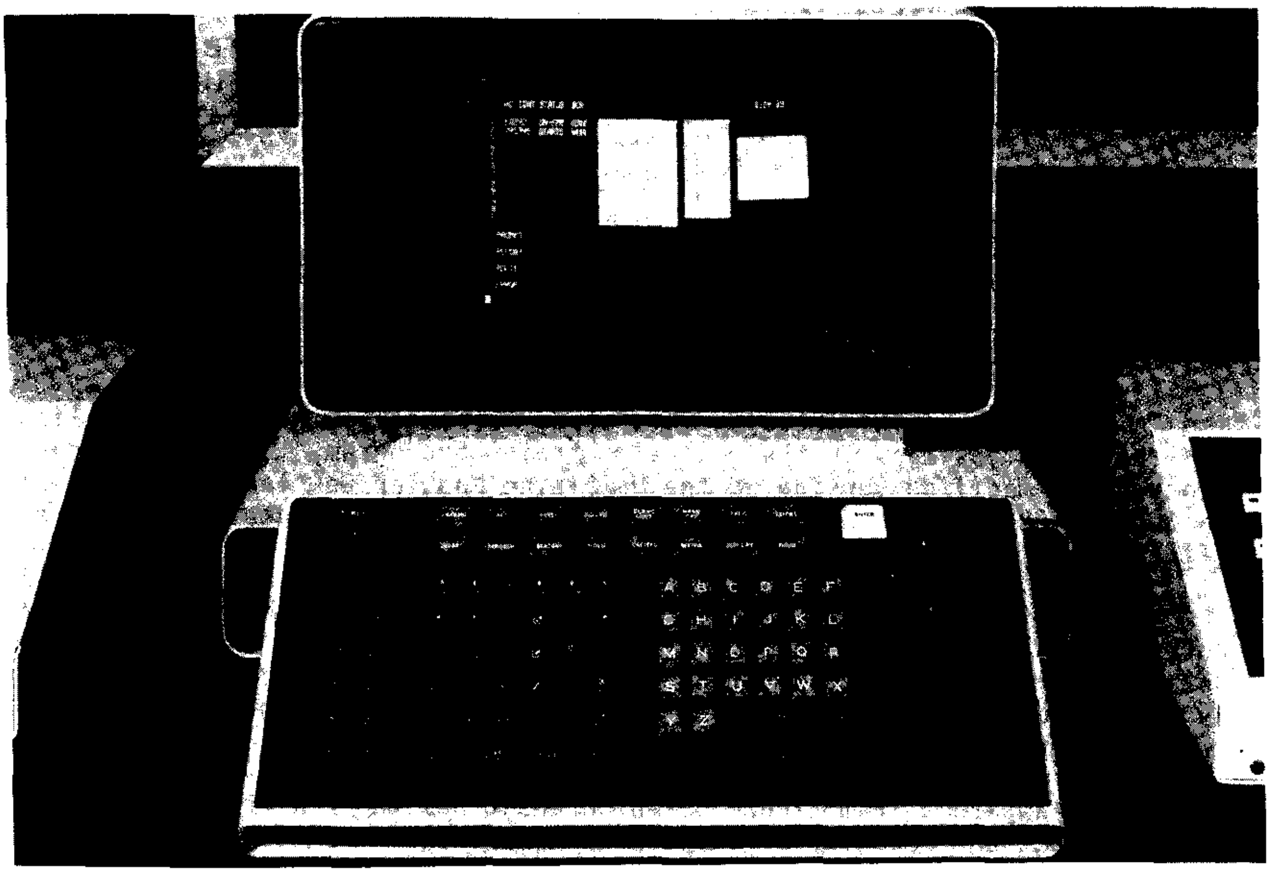


FIGURE 6. Pilot position.

The last focus of the study was on who could/should operate the pilot position. If ATC trainees were to operate the pilot positions, they would spend three times as much time on the pilot positions as they would spend being trained on the radar position. This is undesirable since the pilot position will not be used anywhere in the controller's work after training. In other training systems similar to the RTF, pilot operators are hired to operate the pilot position. Since operating the pilot position is a sedentary task, it could be performed by many handicapped persons, such as those confined to wheelchairs. One of the purposes of the study was to compare error rates and training time for ATC trainees, people from the general community, and handicapped people.

II. Methods.

A. Subjects. There were three separate groups of subjects. Table 2 gives a description of the three groups by number, sex, and age.

Those in Group I were recent graduates of the FAA Academy in nonradar ATC. The selection of Group I subjects was based on Academy scores (Table 3), minority status, sex, and availability for the study.

Group II consisted of paid subjects from the Greater Oklahoma City community who were selected on the basis of the following criteria: They were required to be between the ages of 18 and 45, nonhandicapped, nonstudent, and of average or better intelligence (not classified as mentally handicapped).

Group III consisted of paid subjects from the Greater Oklahoma City community who met the following criteria: They were required to be between the ages of 18 and 50, handicapped (but with normal vision in at least one eye, normal hearing in at least one ear, and at least one arm and hand with no disability exceeding 25 percent), and of average or better intelligence (not classified as mentally handicapped). Table 4 describes Group III by handicap.

Two concerns expressed by Academy personnel regarding pilot training were included in the study design: (1) Does note taking during training impede or enhance the learning process? and, (2) How much academic training is required? To answer these questions, each group was randomly divided into two equal sections; one section was allowed to take notes during the instructional phase and the practice and evaluation exercises while the other section was not allowed to take notes during these times and had to rely on memory. Groups II and III were randomly subdivided further into two equal sections. Section I received approximately 4 hours of classroom academic instruction and Section II received approximately 8 hours.

B. Training System. The complete training system consisted of two independent components, a computer system and a communication system. The computer system comprised a DEC 11/34 computer, dual floppy disk drives, an LA36 Decwriter, and 12 modified Hazeltine Modular One terminals. Each

Table 2. Description of Subjects by Sex and Age

Group	Subject Number	Sex: Men	Sex: Women	Age
Group I	S1	X		21
	S2	X		24
	S3	X		26
	S4	X		25
	S5	X		24
	S6	X		29
	S7	X		29
	S8	X		30
	S9		X	20
	S10	X		27
	S11	X		24
Group II	S12		X	33
	S13		X	
	S14		X	
	S15		X	26
	S16	X		27
	S17		X	
	S18		X	38
	S19		X	21
	S20		X	37
	S21		X	32
	S22		X	
	S23		X	
Group III	S24		X	47
	S25	X		
	S26		X	
	S27	X		
	S28	X		
	S29	X		26
	S30		X	25
	S31		X	39
	S32	X		29
	S33	X		26
	S34		X	43
TOTALS	N=34	N=17	N=17	

Table 3. Distribution of Academy Graduates' Composite Scores (N=11)

Score	Frequency
70	2
71	1
72	1
73	2
74	1
75	0
76	0
77	0
78	2
79	1
80	0
81	1

Table 4. Description of Handicapped Group by Handicap

Subject Number	Type of Handicap: Visual	Wheelchair or Immobile	Hand or Arm Disability	Miscellaneous
S24		X		
S25		X	X	
S26				X
S27			X	
S28				X
S29		X		X
S30		X		X
S31	X			
S32			X	
S33		X	X	X
S34				X

terminal had both a keyboard and a CRT. The communication system consisted of a Superscope Stereo cassette recorder (GS200) and 14 standard ATC headsets, one attached to each position and two available for system monitoring. Figure 7 is a graphic representation of both the system equipment and the individual position equipment.

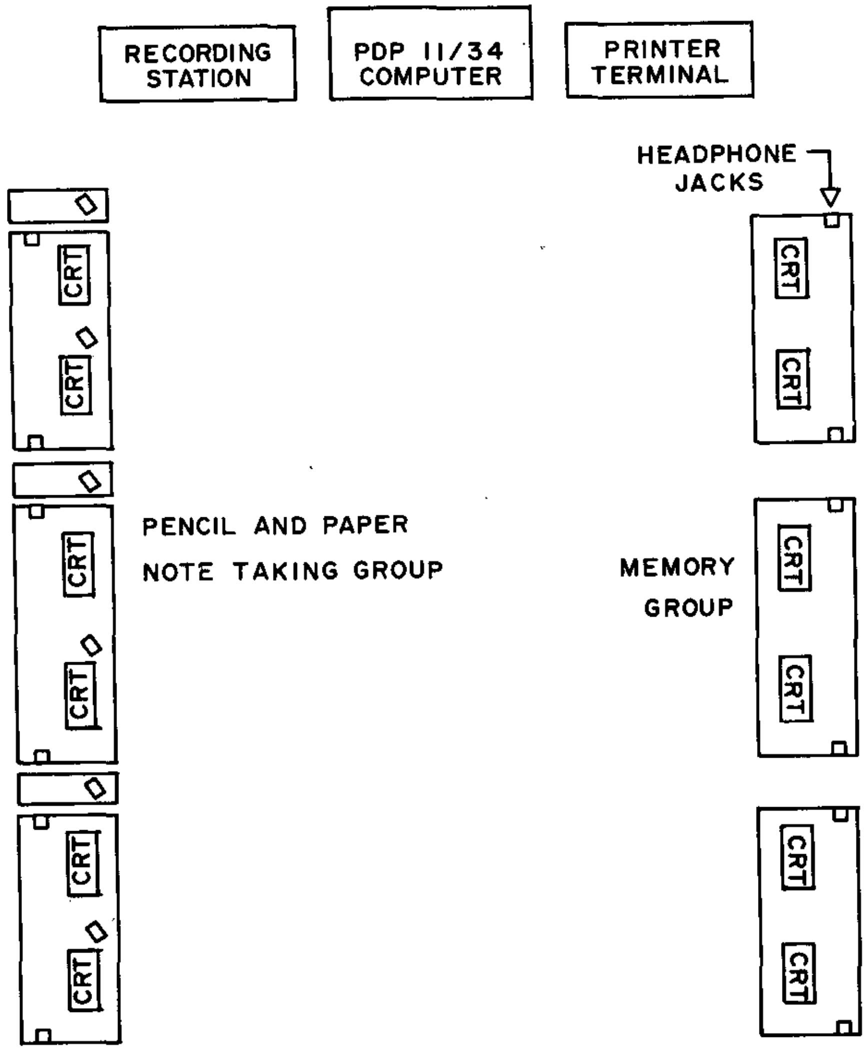


FIGURE 7. Equipment configuration.

The command messages, both for the evaluation and for the practice exercises, were first recorded on floppy disks by using the computer input mode. After the messages were recorded on floppies, they were played back and audio recordings of the messages were made on cassette tapes. The same timing was used for both. During training and evaluation exercises, the prerecorded messages were broadcast simultaneously through the headset to each pilot position. Each command was broadcast only one time. The keyboard response to each command by each subject was recorded by the computer as soon as the subject depressed the ENTER key on the keyboard. The computer then compared the entered response with the correct message which had been previously recorded on the floppy disk. If the response was correct, the computer erased the subject's response from the CRT. If the response was incorrect, the computer recorded the error on another floppy disk and also transmitted an error message to the subject's CRT. Errors were recorded under five different categories. These are listed and described in Table 5. The subject could

Table 5. Summary of Error Definitions

Error Number	Error Type	Definition
1	Flight ID Error	A correct command was entered but the wrong flight (or no flight) was selected at the time of command message entry.
2	Format Error	The correct flight was selected at entry time but an incorrect format was detected in the syntax rules.
3	Flight ID and Format Error	The wrong flight (or no flight) was selected and an incorrect format was detected in the syntax rules.
4	Content Error	A correct flight was selected and no syntax errors were detected but the content of the command was in error.
5	Flight ID and Content Error	The wrong flight (or no flight) was selected and the content of the command was in error.

then either modify the message or delete the incorrect message and reenter the message correctly. When the ENTER key was again depressed after the correction, the message was again cycled through the computer to determine if it was correct. This process was repeated with each command.

The functionally oriented keyboard was divided into software-related functional areas that were color coded. Figure 8 shows the keyboard and the color-coded areas. The first area, consisting of orange keys, was the flight identifier area. These 12 keys were line numbers that corresponded to aircraft listed on the CRT tabular display at each position. They were used as a fast-entry reference to control the flight status of the aircraft targets (see Figure 8). Table 6 contains the aircraft identifications and the corresponding line numbers. One key was selected for each command given; for example, the orange key marked "Line 2" was depressed whenever the command referred to "American fourteen twenty." (See Table 6.) The second area, consisting of 16 blue keys across the top center of the keyboard, was called the function key area (see Figure 8). These keys initiated the primary function of each message and alerted the computer that subsequent information to initiate or change an aircraft's status would be forthcoming. For example, "cleared as filed" was input by depressing the DEPART function key. Some input messages required more than one function key (see Appendix 1 for a listing of the multifunction messages employed in the study). The next area

Table 6. Predefined Flight Identifiers

Line Number	Flight ID	Flight Phraseology
1	UA365	United Three Sixty Five
2	AA1420	American Fourteen Twenty
3	R18745	Army 18745
4	N7398B	November 73 Niner 8 Bravo
5	NA217	National Two Seventeen
6	VV7K512	Navy 7 Kilo 512
7	N71Z	November 71 Zulu
8	A28160	Air Force 28160
9	BN78	Braniff Seventy Eight
A	VM72240	Marine 72240
B	N684WX	November 684 Whiskey X-Ray
C	DL403	Delta Four Oh Three

Note: There are five airline, four military, and three general flights identified above.

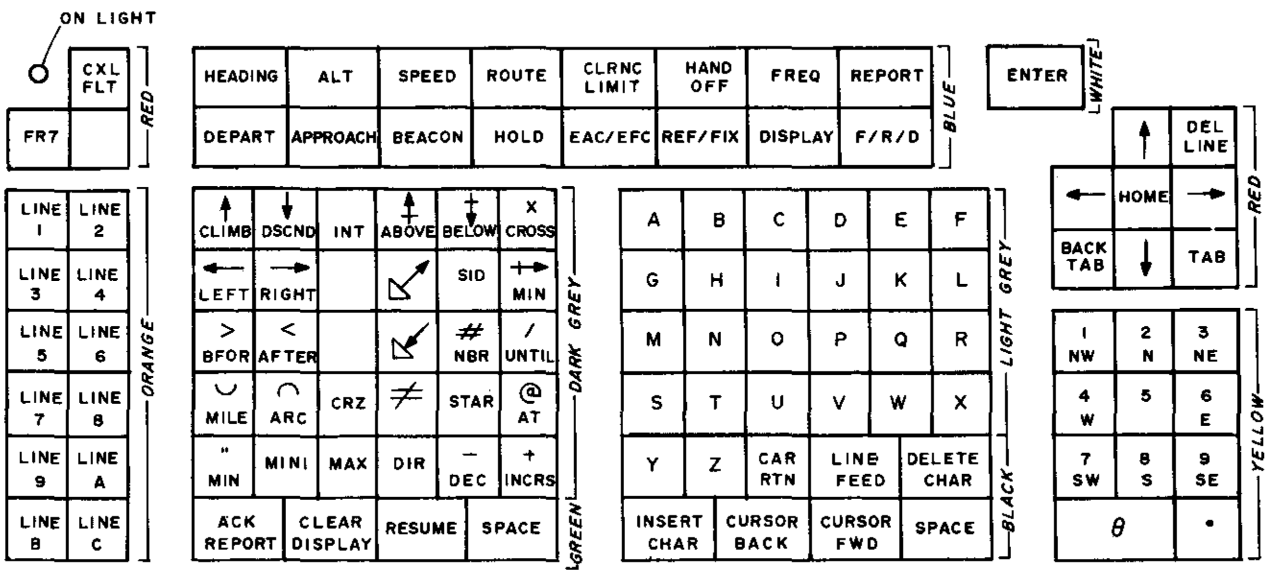


FIGURE 8. Pilot/ghost position keyboard.

of keys (subcommand function keys) was located in the center left of the keyboard or the action key area. The action keys were dark grey with the exception of one action key (RESUME) located in the green key area. The action keys gave the operation or action to be performed for the specified function. For example, "turn left" was input using the HEADING function key and the left arrow action key. The light-grey or alpha keys were used to input any alpha characters required in the messages, such as a STAR (Standard

Arrival) or SID (Standard Instrument Departure) name. The next area, the black keys at the bottom of the alpha area, consisted of seven keys that were mainly used to move the cursor on the CRT and to correct or edit input errors. These keys were called either entry area keys or edit keys. The yellow keys located at the far right of the keyboard were called numeric/direction keys. The keys were depressed to represent numbers in the messages, such as an altitude or heading. If the direction was required in the input message, the DIR key in the action area was first depressed, then the corresponding yellow key was used to indicate the compass direction. For example, the yellow key marked "7" and "SW" indicated the direction southwest when the DIR key was depressed immediately prior to it. The red keys in the upper righthand corner of the keyboard were not operative except for the DEL LINE key, which deleted the entire entry except for the flight ID number. The CLEAR DISPLAY key in the green area was depressed when the subject wished to delete all of his/her entry including the flight ID number.

Figure 9 illustrates the operational steps involved in the training system.

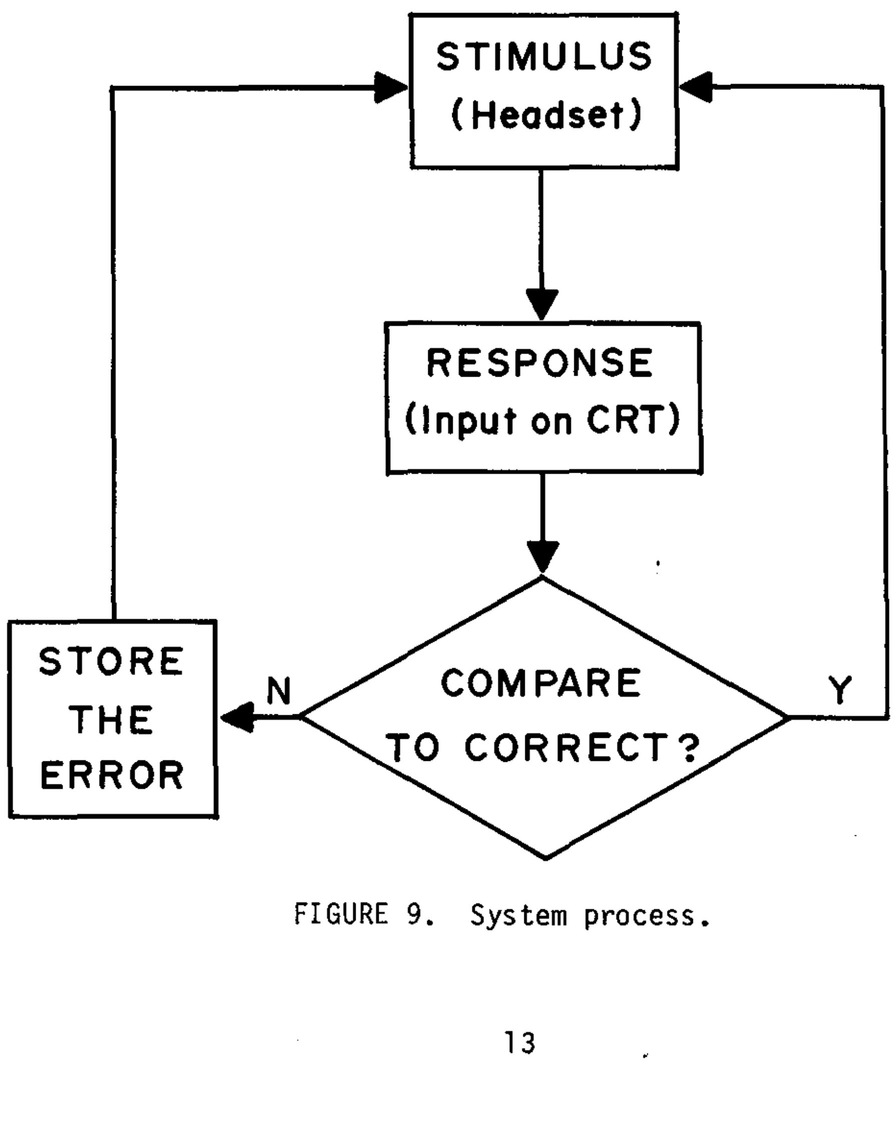


FIGURE 9. System process.

C. <u>Instructional Design</u>. The possible input messages for the pilot position were listed by the manufacturer in an appendix to the computer program functional specifications. Four expert judges, all air traffic control specialists, served as a panel to identify the input messages on the list that are most frequently used in air traffic control simulation problems and the messages that are rarely used. The input messages rarely used were eliminated and a new list containing 50 items was formed. The new list was divided into categories of messages according to the number of key depressions required to input the message. Ten categories, placed in order of increasing difficulty, constituted the final list of input message types taught in the pilot training. Examples of input messages based on the 50 message types are listed by category in Appendix 1.

The amount of time allowed to input a particular message type was established as follows. Several naive noncontroller subjects were used to determine how much time a beginner would require to input each message. The average time required by the naive subjects to input the messages in each of the categories was used as the 100-percent time allotment. Table 7 contains the 100-percent time allotment assigned to each input message category. Each input message category was taught separately, beginning with category 1. Instructors taught the first command in the category and the keys necessary to enter the command at the keyboard. Time was allowed for any questions or clarification, then subjects were given practice time to enter the command at the keyboard in the form of a dry run. The dry runs consisted of 3 to 5 minutes of recorded messages of only that command. Time was then given for any questions before going on to the next command. After all commands in a category were taught, the subjects were given a practice problem covering all the commands in that category. The 100-percent time limit was allowed on the first run. Two practice problems A and B for each category were designed at the 100-percent time limit and the same two problems were constructed at 75 percent of the 100-percent time limit. The practice problems were alternated when given until the established criterion was met or three trials were attempted. The criterion to be reached was for 90 percent of the subjects to enter 90 percent of the messages correctly (90 percent/90 percent). If the criterion was not met for the practice problem, there was a remedial review; then the second problem of the same difficulty was administered with the same time limit. If the criterion again was not met, more review and practice time were given, and the practice problem was repeated to a maximum of three trials before proceeding to the next category. An illustration of the instructional modules is given in Figure 10.

After completing the 10 categories, the subjects were given five evaluation problems. The evaluation problems contained 50 messages taken from each of the 10 categories. All command types were represented in the problems. The first evaluation problem was designed at 100-percent time allotment. The time allotments for the second, third, fourth, and fifth evaluation problems were decremented by category and administered as shown in Figure 11.

Table 7. One-Hundred-Percent Practice and One-Hundred-Percent Evaluation Exercises

Command Categories	Time Allowed in Exercise (100%)	Time Allowed in Dry Runs	Number of Commands in Evaluation Exercise	Number of Commands in Practice Exercise
Category 1	20 seconds	3 minutes	5	10
Category 2	30 seconds	3 minutes	16	10
Category 3	50 seconds	3 minutes	12	8
Category 4	60 seconds	4 minutes	5	8
Category 5	60 seconds	4 minutes	4	8
Category 6	75 seconds	4 minutes	2	8
Category 7	75 seconds	4 minutes	1	8
Category 8	75 seconds	4 minutes	1	5
Category 9	120 seconds	4 minutes	3	5
Category 10	120 seconds	5 minutes	1	5

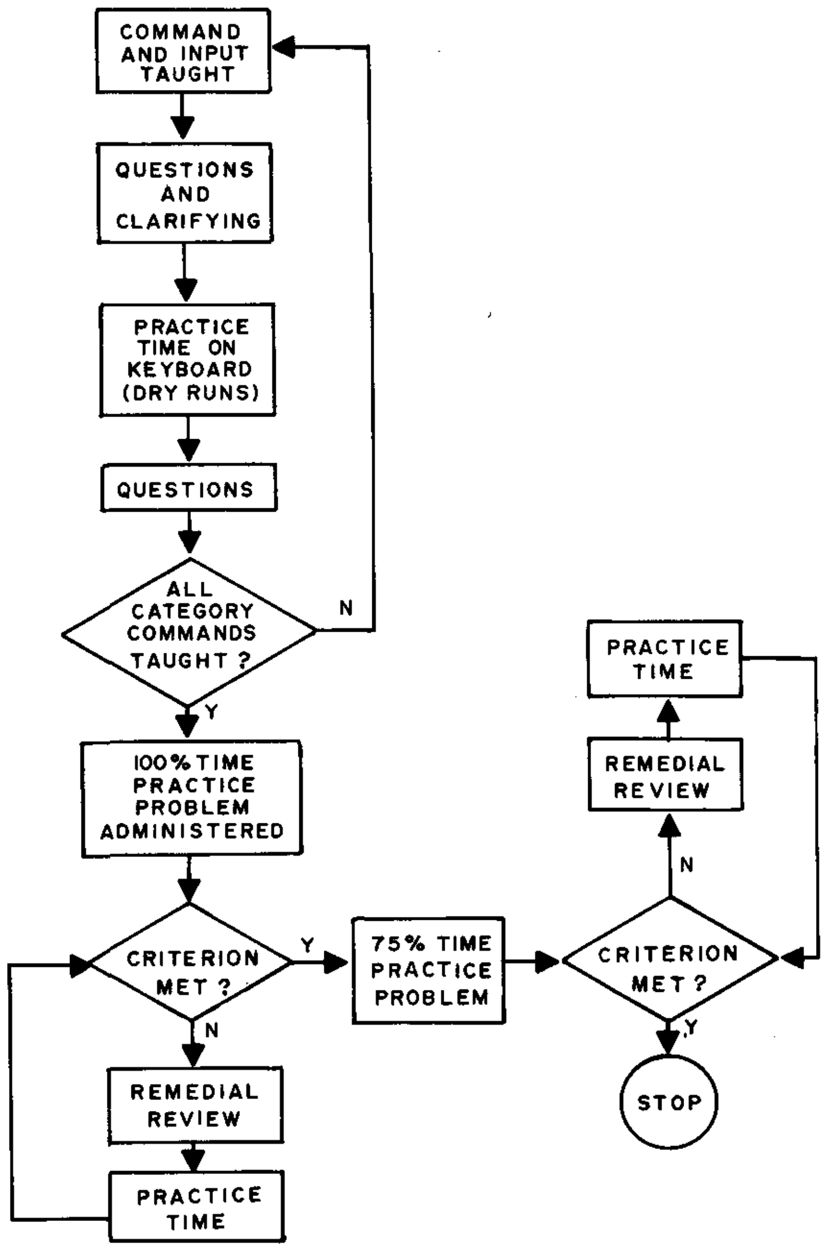


FIGURE 10. Practice session module.

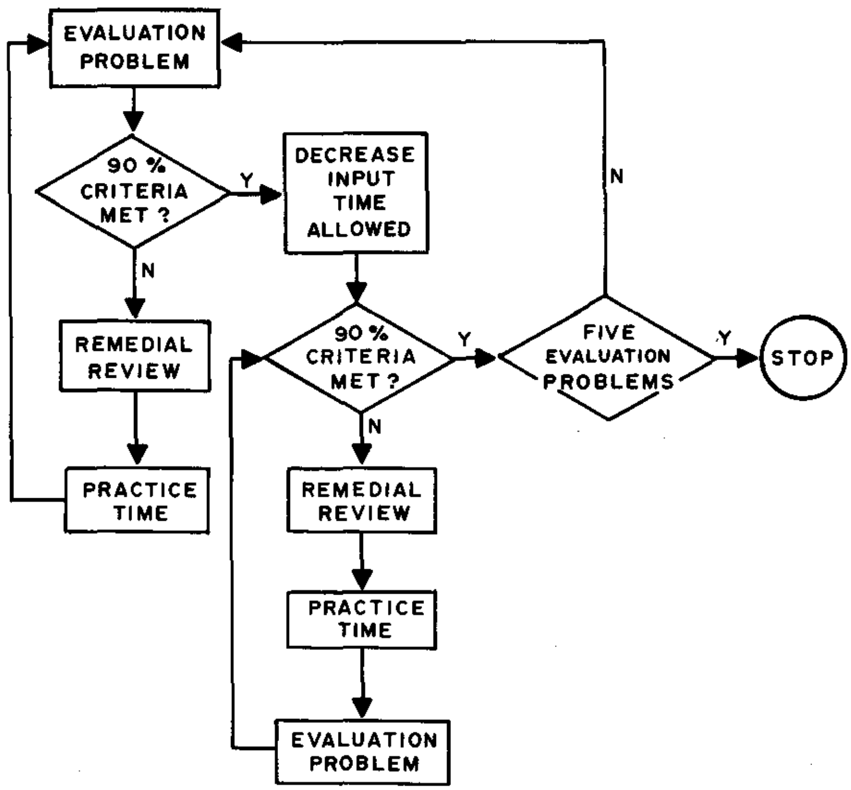


FIGURE 11. Evaluation process module.

Subjects were given three attempts to reach the 90-percent/90-percent criterion on the evaluation problems. If the criterion was not met on the first trial, there was a remedial review and practice time on the most frequently missed messages. The evaluation problem was run again. Once the criterion was met or the three attempts were made, the next evaluation problem was run with the input time allowed decreased as indicated on Figure 11. The usual day consisted of 6 hours of training with a 1-hour lunch break and a 10-minute break each hour.

D. Measures.

1. When a comparison took place within the computer between the messages input by the subjects and the correct inputs, three measures were made:

a. Attempts: Number of attempts to input messages.
b. Errors: Number of incorrect entries.
c. Raw Scores: Computed by subtracting errors from attempts.

2. Academy scores were maintained for Group I.

3. The Dial Reading Test and the Directional Headings Test were administered to all subjects prior to beginning pilot training.

4. Demographic data were collected by means of a biographical questionnaire (see Appendix 2).

5. Following the completion for instruction and practice problems for each category, an evaluation form was administered (see Appendix 3).

6. Following the completion of the evaluation problems, a keyboard evaluation questionnaire was administered (see Appendix 4).

7. Lastly, a record of the number of trials required to complete each category was recorded.

E. Analyses.

1. Descriptive statistics were computed for all relevant variables in the form of means, standard deviations, sample sizes, and intercorrelations.

2. Scores on the Dial Reading Test and the Directional Headings Test were regressed on raw score performance in the evaluation problems to determine how well the test predicted performance and to determine the appropriate weights to be employed in forming composites for selection purposes. A cut point was established by forming a distribution of the composite score (in rank order) and raw performance scores. A judgment was then made by observing where the raw scores made a drop at the lower end of the composite distribution.

3. Data on the evaluation forms were summarized by totaling the frequency of responses for each item on each response scale.

4. A three-way multifactor analysis of variance (Anova) was computed on (i) the independent dimensions of group membership, (ii) whether or not the subjects were allowed to take notes, and (iii) whether the subjects received "long" academic training or "short" academic training. (See Table 8 below for the orthogonal design matrix employed in the regression to perform the Anovas.) Raw performance score was used as the dependent variable.

5. Graphs were formed by plotting attempts, errors, and raw scores by command categories 1 through 10 and by evaluation exercises 1 through 5 for Groups I, II, and III. The number of trials required for reaching the criteria were plotted across exercises 1 through 5.

6. Amount of training time required was computed by summing the number of hours required to reach proficiency.

Table 8. Orthogonal Design Matrix

Main Effects				Interactions				
Notes vs. No Notes (N)	Long/Short Academic (A)	Group Membership (G)		N/A	N/G		A/G	
1	1	1	1	1	1	1	1	1
1	-1	1	1	-1	1	1	-1	-1
1	1	-1	1	1	-1	1	-1	1
1	-1	-1	1	-1	-1	1	1	-1
1	1	0	-2	1	0	-2	0	-2
1	-1	0	-2	-1	0	-2	0	2
-1	1	1	1	-1	-1	-1	1	1
-1	-1	1	1	1	-1	-1	-1	-1
-1	1	-1	1	-1	1	-1	-1	1
-1	-1	-1	1	1	1	-1	1	-1
-1	1	0	-2	-1	0	2	0	-2
-1	-1	0	-2	1	0	2	0	2

III. Results.

Descriptive statistics on all relevant variables are listed in Tables 9 and 10. The primary descriptive statistics to note are the intercorrelations between raw scores, attempts, and errors with the Dial Reading Test, the Directional Headings Test, Group Membership, note taking vs. no note taking, and long or short academic training.

Table 11 lists the regression model for the Dial Reading Test and the Directional Headings Test in predicting raw score performance and the F test for significance. Note the size of the "p" value on the F test.

Tables 12 and 13 summarize the response frequencies on the practice problem evaluation form and the keyboard evaluation form, respectively.

Table 14 is the source table for the multifactor analysis of variance.

Figures 12 through 20 contain the graphs for attempts, raw scores, and errors across command categories and evaluation exercises and the number of trials for each evaluation exercise for all three groups.

IV. Discussion.

A. Descriptive Statistics. It can be noted in Table 10 that raw scores correlate 0.674 with the Dial Reading Test and 0.638 with the Directional Headings Test. This indicates high positive ability for these two tests to predict raw score performance. Further, raw score has a -0.575 correlation with group membership indicating a high relationship between being in a

Table 9. Means, Standard Deviations, and Sample Sizes for Pilot Study Variables

Variables	Means	Standard Deviations	Sample Sizes
Attempts	46.68	3.37	28
Error Prob 1	0.25	0.52	28
Error Prob 2	1.18	1.25	28
Error Prob 3	0.37	0.74	28
Error Prob 4	1.61	1.34	28
Error Prob 5	0.04	0.19	28
Error Total	3.04	2.33	28
Raw Score	43.64	4.18	28
Trials	2.61	0.50	28
Error Message Type 1	0.04	0.19	28
Error Message Type 2	0.43	0.69	28
Error Message Type 3	0.68	0.94	28
Error Message Type 4	0.39	0.69	28
Error Message Type 5	0.14	0.36	28
Error Message Type 6	0.21	0.42	28
Error Message Type 7	0.18	0.48	28
Error Message Type 8	0.14	0.36	28
Error Message Type 9	0.71	0.90	28
Error Message Type 10	0.11	0.31	28
Dial Reading	31.71	12.33	31
Table Reading 1	27.00	10.15	20
Table Reading 2	26.30	11.42	20
Table Reading Total	80.45	28.91	20
Directional Heading 1	19.91	11.12	34
Directional Heading 2	19.82	11.61	34
Directional Heading Total	39.74	22.04	34
Group Membership	2.00	0.82	34
Paper-Pencil Note Taking	1.50	0.51	34
Short/Long Academics	1.48	0.51	23

Table 10. Correlation Matrix for Pilot Performance Measurements

	ATT	ER1	ER2	ER3	ER4	ER5	ERT	RAW	TRI	EC1	EC2	EC3
ATT	1.000 28	0.027 28	-0.153 28	-0.162 27	0.063 28	0.430 27	-0.046 28	0.830 28	-0.122 28	0.135 28	0.364 28	-0.232 28
ER1		1.000 28	-0.129 28	-0.147 27	0.093 27	-0.069 27	0.207 28	-0.094 28	0.251 28	0.284 28	0.311 28	0.095 28
ER2			1.000 28	0.149 27	0.551 28	0.106 27	0.824 28	-0.583 28	0.356 28	-0.028 28	0.381 28	0.584 28
ER3				1.000 27	-0.168 27	-0.082 27	-0.039 27	-0.203 27	0.186 27	-0.118 27	0.004 27	0.511 27
ER4					1.000 28	-0.016 27	0.891 28	-0.456 28	0.481 28	-0.235 28	0.668 28	0.510 28
ER5						1.000 27	0.381 27	-0.153 27	-0.127 27	-0.065 27	-0.145 27	-0.120 27
ERT							1.000 28	-0.594 28	0.623 28	-0.087 28	0.657 28	0.627 28
RAW								1.000 28	-0.390 28	0.157 28	-0.073 28	-0.536 28
TRI									1.000 28	0.155 28	0.186 28	0.431 28
EC1										1.000 28	-0.122 28	-0.141 28
EC2											1.000 28	0.276 28
EC3												1.000 28

	EC4	EC5	EC6	EC7	EC8	EC9	E10	DR
ATT	-0.361 28	0.132 28	-0.528 28	-0.009 28	-0.238 28	0.373 28	0.034 28	0.482 28
ER1	0.026 28	0.201 28	-0.086 28	0.263 28	-0.201 28	-0.092 27	0.057 28	-0.237 28
ER2	0.218 28	0.273 28	0.350 28	0.007 28	0.357 28	0.576 28	0.232 28	-0.474 28
ER3	-0.099 27	-0.128 27	-0.012 27	-0.170 27	0.178 27	-0.068 27	-0.236 27	-0.066 27
ER4	0.053 28	0.122 28	0.354 28	0.288 28	0.122 28	0.765 28	0.278 28	-0.360 28
ER5	0.206 27	-0.110 27	0.882 27	-0.080 27	0.084 27	-0.128 27	0.297 27	0.050 27
ERT	0.153 28	0.261 28	0.372 28	0.228 28	0.216 28	0.749 28	0.297 28	-0.514 28
RAW	-0.376 28	-0.039 28	-0.633 28	-0.134 28	-0.312 28	-0.117 28	-0.139 28	0.674 28
TRI	0.035 28	0.328 28	0.242 28	0.151 28	0.119 28	0.403 28	-0.194 28	-0.485 28
EC1	-0.112 28	0.471 28	-0.101 28	-0.074 28	-0.079 28	-0.156 28	-0.067 28	-0.013 28
EC2	-0.056 28	0.194 28	0.055 28	-0.016 28	-0.108 28	0.564 28	0.292 28	-0.059 28
EC3	-0.255 28	0.471 28	0.275 28	-0.032 28	0.141 28	0.237 28	-0.004 28	-0.617 28
EC4	1.000 28	-0.238 28	-0.046 28	-0.110 28	0.368 28	0.009 28	-0.031 28	-0.114 28
EC5		1.000 28	-0.213 28	-0.156 28	-0.167 28	0.017 28	-0.141 28	-0.436 28
EC6			1.000 28	0.173 28	0.036 28	0.169 28	0.101 28	-0.405 28
EC7				1.000 28	-0.156 28	0.211 28	0.115 28	-0.261 28
EC8					1.000 28	0.017 28	-0.141 28	0.033 28
EC9						1.000 28	0.244 28	-0.087 28
E10							1.000 28	0.064 28
DR								1.000 31

	TR1	TR2	TOT	DH1	DH2	DHT	GP	PEN	ACA
ATT	0.693 17	0.806 17	0.752 17	0.363 28	0.492 28	0.442 28	-0.329 28	-0.032 28	-0.049 17
ER1	0.108 17	0.099 17	0.060 17	-0.370 28	-0.257 28	-0.327 28	0.375 28	0.070 28	-0.311 17
ER2	-0.102 17	-0.116 17	-0.179 17	-0.349 28	-0.445 28	-0.411 28	0.358 28	0.204 28	-0.295 17
ER3	-0.526 16	-0.639 16	-0.593 16	0.164 27	-0.136 27	0.018 27	0.056 27	-0.015 27	-0.048 16
ER4	-0.093 17	0.162 17	-0.062 17	-0.348 28	-0.364 28	-0.369 28	0.489 28	0.244 28	0.165 28
ER5	-0.558 16	0.020 16	-0.331 16	0.037 27	0.045 27	0.042 27	-0.210 27	0.189 27	0.209 16
ERT	-0.088 17	0.053 17	-0.123 17	-0.470 28	-0.504 28	-0.505 28	0.557 28	0.265 28	-0.161 17
RAW	0.679 17	0.706 17	0.752 17	0.554 28	0.677 28	0.638 28	-0.575 28	-0.174 28	0.043 17
TRI	-0.582 16	-0.519 16	-0.531 16	-0.715 28	-0.665 28	-0.717 28	0.887 28	0.073 28	-0.126 16
EC1	0.114 17	0.219 17	0.154 17	-0.088 28	0.064 28	-0.015 28	0.016 28	0.192 28	-0.299 17
EC2	0.329 17	0.289 17	0.234 17	-0.119 28	-0.033 28	-0.080 28	0.241 28	0.316 28	-0.222 17
EC3	-0.230 17	-0.289 17	-0.423 17	-0.394 28	-0.612 28	-0.519 28	0.428 28	0.269 28	-0.116 17
EC4	-0.019 17	-0.247 17	-0.071 17	-0.105 28	-0.119 28	-0.116 28	0.113 28	-0.159 28	0.153 17
EC5	0.138 17	0.087 17	-0.082 17	-0.302 28	-0.336 28	-0.331 28	0.156 28	0.204 28	-0.099 17
EC6	-0.693 17	-0.486 17	-0.573 17	-0.378 28	-0.434 28	-0.421 28	0.458 28	0.174 28	0.015 17
EC7	-0.316 17	0.067 17	-0.138 17	-0.354 28	-0.188 28	-0.284 28	0.214 28	-0.229 28	0.142 17
EC8	0.004 17	0.053 17	0.102 17	0.165 28	0.056 28	0.116 28	0.035 28	0.204 28	-0.240 17
EC9	0.200 17	0.458 17	0.314 17	-0.184 28	-0.184 28	-0.191 28	0.358 28	0.081 28	0.527 16
E10	0.140 17	0.070 17	0.172 17	-0.041 28	0.093 28	0.025 28	-0.108 28	0.115 28	-0.299 17
DR	0.722 20	0.637 20	0.904 20	0.717 31	0.832 31	0.800 31	-0.578 31	-0.103 31	-0.140 20
TR1	1.000 20	0.571 20	0.865 20	0.558 20	0.781 20	0.713 20	-0.549 20	0.000 20	-0.173 20
TR2		1.000 20	0.850 20	0.541 20	0.631 20	0.622 20	-0.364 20	-0.292 20	-0.174 20
TOT			1.000 20	0.627 20	0.844 20	0.783 20	-0.485 20	-0.178 20	-0.185 20
DH1				1.000 34	0.879 34	0.968 34	-0.797 34	-0.153 34	0.186 23
DH2					1.000 34	0.971 34	-0.726 34	-0.082 34	0.090 23
DHT						1.000 34	-0.785 34	-0.121 34	0.143 23
GP							1.000 34	0.073 34	-0.045 23
PEN								1.000 34	-0.129 23
ACA									1.000 23

Table 11. Regression Model

Model 1 Criterion = 2
Predictors = 4- 4 10-10

R = 0.6921 RSQ = 0.4789 2 Iterations

V	BETA	B
4	0.4389	0.1488
10	0.2889	0.0548

REG. CONST. = 36.7446

F-TEST 1 DRT & DHT PREDICTION OF RAW SCORE
RSQ FULL = 0.4789 MODEL 1
RSQ REDUCED = 0.0000 MODEL 0
DIFFERENCE = 0.4789
DFN = 2. DFD = 25. F-RATIO = 11.490 P = 0.00049

* * *

Table 12. Evaluation Form for Practice Modules

Directions: Circle the response that best expresses your observation, make comments, where appropriate.

1. Were the commands taught clearly?

Unclear	Average Clear	Very Clear
CAT. 1 - 0	CAT. 1 - 7	CAT. 1 - 24
CAT. 2 - 0	CAT. 2 - 21	CAT. 2 - 9
CAT. 3 - 0	CAT. 3 - 9	CAT. 3 - 23
CAT. 4 - 0	CAT. 4 - 13	CAT. 4 - 18
CAT. 5 - 0	CAT. 5 - 14	CAT. 5 - 16
CAT. 6 - 0	CAT. 6 - 10	CAT. 6 - 20
CAT. 7 - 0	CAT. 7 - 11	CAT. 7 - 19
CAT. 8 - 0	CAT. 8 - 8	CAT. 8 - 22
CAT. 9 - 2	CAT. 9 - 10	CAT. 9 - 17
CAT. 10 - 0	CAT. 10 - 7	CAT. 10 - 22
2	110	190

(Table 12 continued on following page)--

Table 12 (continued)--

2. Was enough practice time given? (Dry runs)

Not Enough Time Given	Enough Time Given	Too Much Time Given
CAT. 1 - 0	CAT. 1 - 21	CAT. 1 - 9
CAT. 2 - 0	CAT. 2 - 20	CAT. 2 - 10
CAT. 3 - 0	CAT. 3 - 22	CAT. 3 - 10
CAT. 4 - 0	CAT. 4 - 21	CAT. 4 - 8
CAT. 5 - 0	CAT. 5 - 25	CAT. 5 - 4
CAT. 6 - 0	CAT. 6 - 23	CAT. 6 - 5
CAT. 7 - 0	CAT. 7 - 21	CAT. 7 - 7
CAT. 8 - 0	CAT. 8 - 22	CAT. 8 - 6
CAT. 9 - 1	CAT. 9 - 25	CAT. 9 - 1
CAT. 10 - 1	CAT. 10 - 22	CAT. 10 - 5
2	222	65

3. Were the verbal commands given during the practice exercises understandable? (Cassette recordings)

	Not Understandable	Understandable	Easily Understood
	CAT. 1 - 2	CAT. 1 - 15	CAT. 1 - 15
1	CAT. 2 - 1	CAT. 2 - 13	CAT. 2 - 13
	CAT. 3 - 1	CAT. 3 - 17	CAT. 3 - 12
	CAT. 4 - 4	CAT. 4 - 19	CAT. 4 - 7
	CAT. 5 - 1	CAT. 5 - 21	CAT. 5 - 7
	CAT. 6 - 3	CAT. 6 - 17	CAT. 6 - 7
	CAT. 7 - 4	CAT. 7 - 19	CAT. 7 - 7
	CAT. 8 - 5	CAT. 8 - 17	CAT. 8 - 7
2	CAT. 9 - 1	CAT. 9 - 22	CAT. 9 - 3
	CAT. 10 - 2	CAT. 10 - 17	CAT. 10 - 8
	24	177	86

4. Was the timing of the commands in the practice exercise spaced appropriately?

Not Enough Time Given	Enough Time Given	Too Much Time Given
CAT. 1 - 0	CAT. 1 - 18	CAT. 1 - 11
CAT. 2 - 0	CAT. 2 - 20	CAT. 2 - 10
CAT. 3 - 0	CAT. 3 - 17	CAT. 3 - 15

(Table 12 continued on following page)--

Table 12 (continued)--

CAT. 4 - 1	CAT. 4 - 17	CAT. 4 - 12
CAT. 5 - 0	CAT. 5 - 17	CAT. 5 - 12
CAT. 6 - 0	CAT. 6 - 18	CAT. 6 - 10
CAT. 7 - 0	CAT. 7 - 20	CAT. 7 - 9
CAT. 8 - 0	CAT. 8 - 22	CAT. 8 - 7
CAT. 9 - 1	CAT. 9 - 20	CAT. 9 - 6
CAT. 10 - 1	CAT. 10 - 18	CAT. 10 - 9
3	187	101

5. Did you note any possible errors in the commands given during practice exercise? (Please list errors below.)

6. Feel free to make any comments or suggestions that you think would improve the methods employed in this practice module.

   COMMENTS OR SUGGESTIONS:

* * *

Table 13. Pilot Study Evaluation for Keyboard

Circle the response that best expresses your observations or make comments where appropriate. The percentages for each response are indicated in parentheses.

1. Did you find the color scheme helpful in locating the keys?

Not Helpful	Helpful	Very Helpful	No Difference
0	14 (.50)	10 (.36)	4 (.14)

2. What is your impression of how the keyboard is set up in regard to the following?

	Not Helpful	Helpful	Very Helpful
A. Flight ID Keys (orange)	0 (0)	20 (.71)	8 (.29)

(Table 13 continued on following page)--

Table 13 continued--

B. Function Keys (blue)	1 (.04)	18 (.64)	9 (.32)
C. Action Keys (dark grey)	3 (.11)	18 (.64)	7 (.25)
D. Display Keys (green)	5 (.18)	17 (.61)	6 (.21)
E. Alpha Keys (light grey)	6 (.21)	16 (.57)	6 (.21)
F. Entry Keys (black) 1 blank	4 (.14)	16 (.57)	8 (.29)
G. Numeric/Direction Keys (yellow)	7 (.25)	11 (.39)	10 (.36)
	$\bar{X}$=(.13)	$\bar{X}$=(.59)	$\bar{X}$=(.28)

3. Do you think that the ALPHA keys would be more efficient if they were arranged in the same order as on a typewriter?

No	Maybe	Yes	No Difference
8 (.29)	7 (.25)	10 (.36)	3 (.10)

4. Do you think that the NUMERIC/DIRECTION keys would be more efficient if they were arranged in the same order as on a 10-key adding machine?

No	Maybe	Yes	No Difference
9 (.32)	4 (.14)	10 (.36)	5 (.18)

5. Which do you feel would be the best arrangement for the FLIGHT ID keys?

In Order (9) (.32)		Alternated (19) (.68)	
1	7	1	2
2	8	3	4
3	9	5	6
4	A	7	8
5	B	9	A
6	C	B	C

(Table 13 continued on following page)--

Table 13 continued--

6. Do you think it would be helpful if the ACTION keys were positioned on the right side and the ALPHA keys were positioned on the left side?

Not Helpful	Helpful	Very Helpful	No Difference
12 (.43)	3 (.11)	2 (.07)	11 (.39)

7. Do you think the position of the ENTER key is best where it is?

Better Somewhere Else (Where?)	No Difference	Best There
10 (.36)	6 (.21)	12 (.43)

8. Do you think the FUNCTION keys are better at the bottom or the top of the keyboard?

1 blank	Bottom	Top	Better Somewhere Else (Where?)
(.04)	2 (.07)	25 (.89)	0 (0)

9. Was it helpful having two SPACE keys?

Not Helpful	Helpful	Very Helpful	No Difference
18 (.64)	2 (.07)	0	8 (.29)

10. Did the non-functional keys:

	No	Sometimes	Yes	No Difference
A. Cause you to make mistakes?	18 (.64)	7 (.25)	0 (0)	3 (.11)
B. Slow you down? 1 blank	17 (.61)	7 (.25)	0 (0)	4 (.14)

11. Do you think that the CARRIAGE RETURN key should be moved?

3 blank	No	Yes	No Difference
(.11)	4 (.14)	2 (.07)	19 (.68)

12. Would it be helpful to have the ACTION keys further apart?

Not Helpful	Helpful	Very Helpful	No Difference
10 (.36)	5 (.18)	0 (0)	13 (.46)

13. Is it confusing having the MIN ("), MINI, and MAX ACTION keys right next to each other?

No	Sometimes	Yes	No Difference
14 (.50)	6 (.21)	5 (.18)	3 (.11)

(Table 13 continued on following page)--

Table 13 continued--

14. Were the ENTRY keys helpful in correcting your mistakes?

Not Helpful	Helpful	Very Helpful	No Difference
6 (.21)	10 (.36)	7 (.25)	5 (.18)

15. Which of the following keys did you use to correct mistakes?

	Never	Rarely	Sometimes	Mostly
A. Delete Character	0 (0)	0 (0)	15 (.58)	11 (.42)
B. Delete Line	0 (0)	1 (.03)	14 (.52)	12 (.45)
C. Clear Display	3 (.12)	10 (.39)	11 (.42)	2 (.07)

16. Would it be helpful to have the DIR ACTION key closer to the NUMERIC/ DIRECTION keys?

Not Helpful	Helpful	Very Helpful	No Difference
5 (.18)	11 (.40)	6 (.21)	6 (.21)

* * *

Table 14. Source Table for Multifactor Anova

Source	DF	F	P
Main Effects			
Groups (G)	2	20.724	.000006
Notes/No Notes (N)	1	.002	.9647
Short/Long Academics (A)	1	.429	.5187
Interaction Effects			
G/N	2	.114	.8927
G/A	2	.139	.8709
N/A	1	.017	.8973
G/N/A	5	.100	.9912

* * *

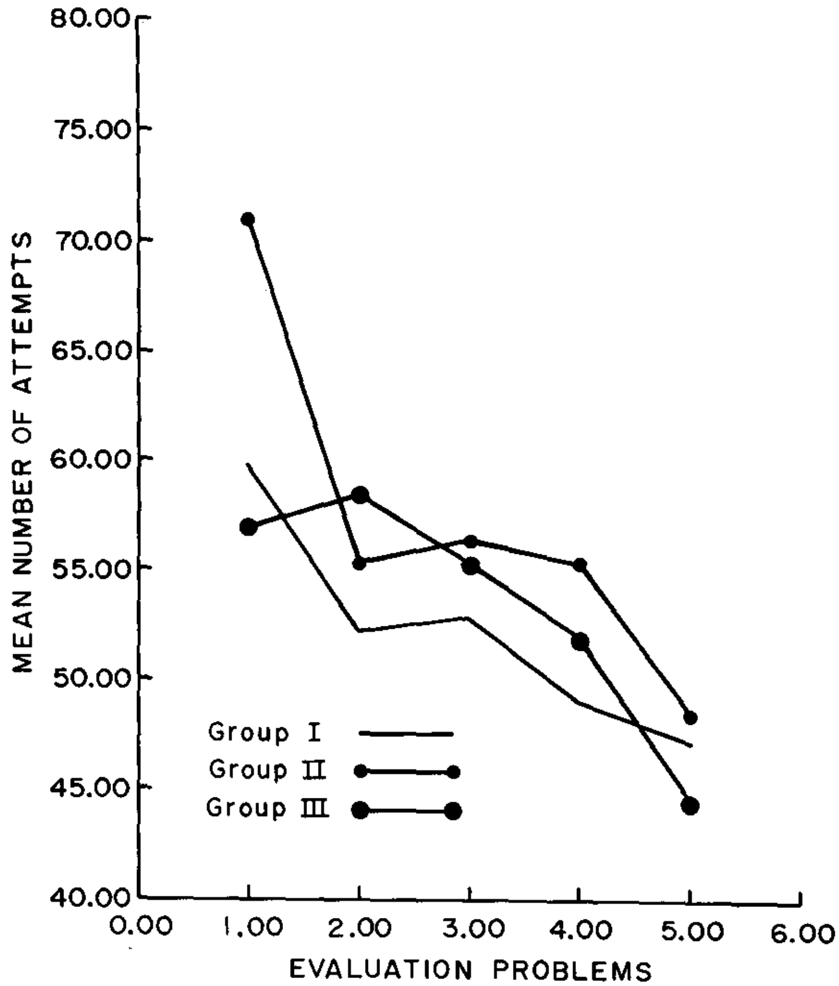


FIGURE 12. Attempts on evaluation problems.

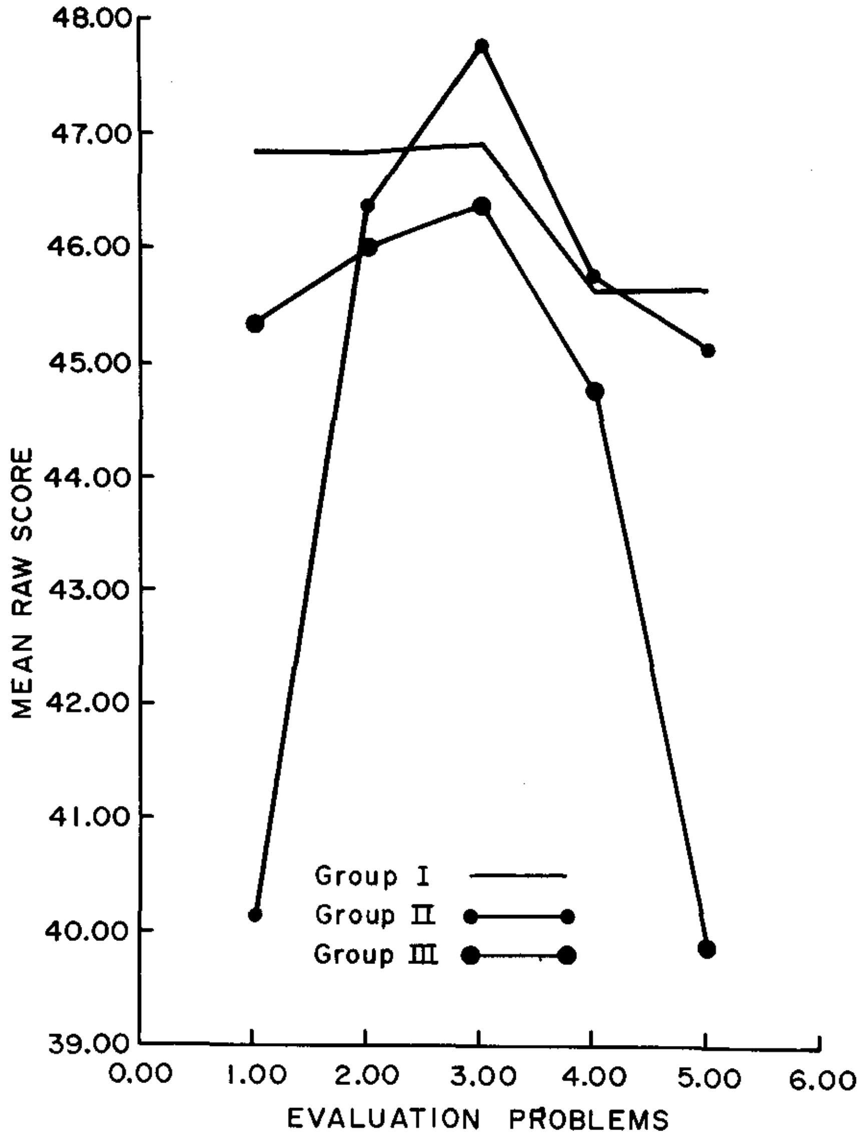


FIGURE 13. Raw score on evaluation problems.

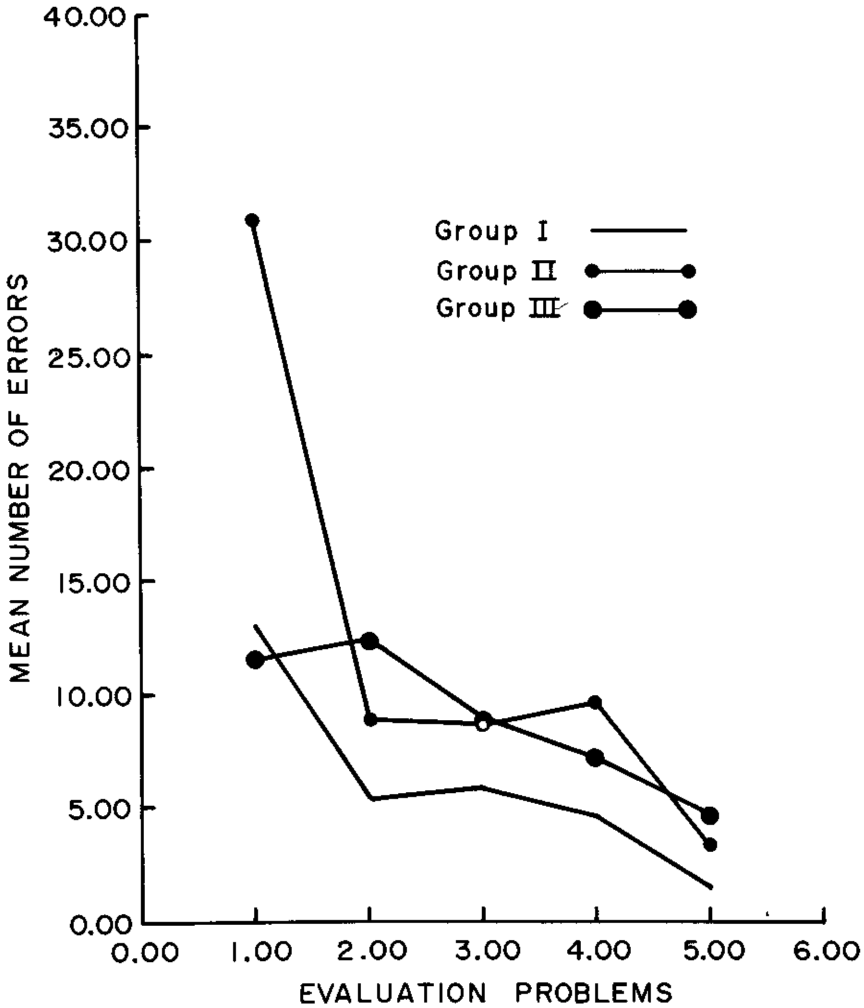


FIGURE 14. Errors on evaluation problems.

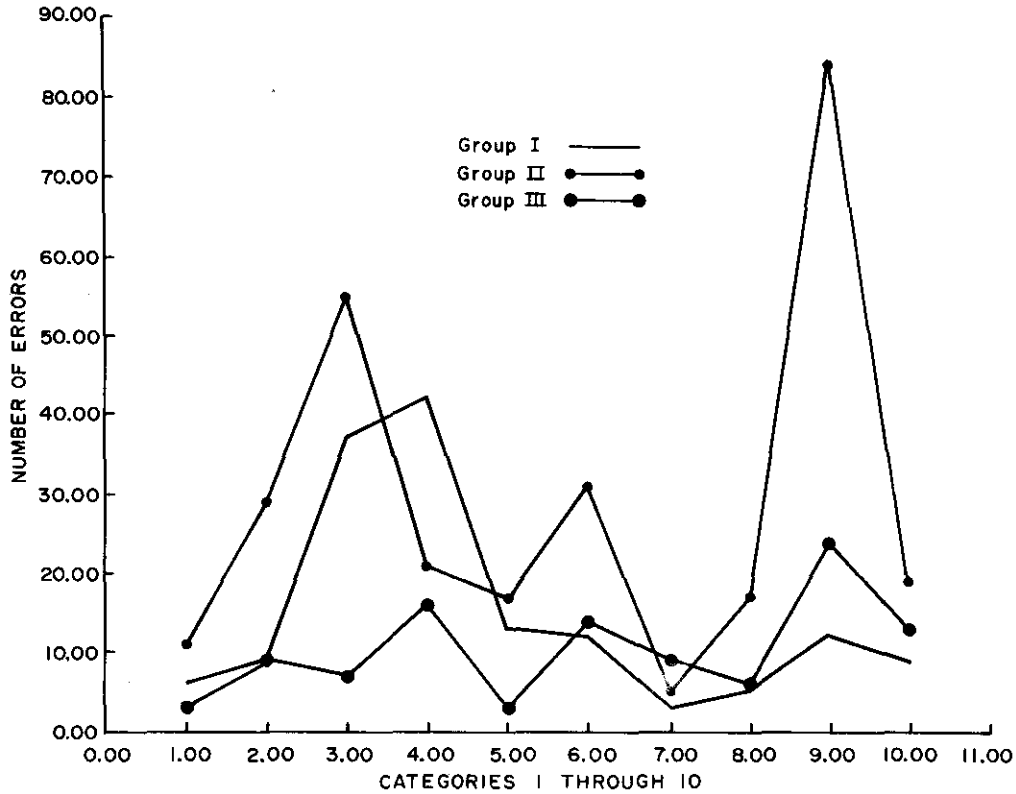


FIGURE 15. Errors by category (evaluation problem 1).

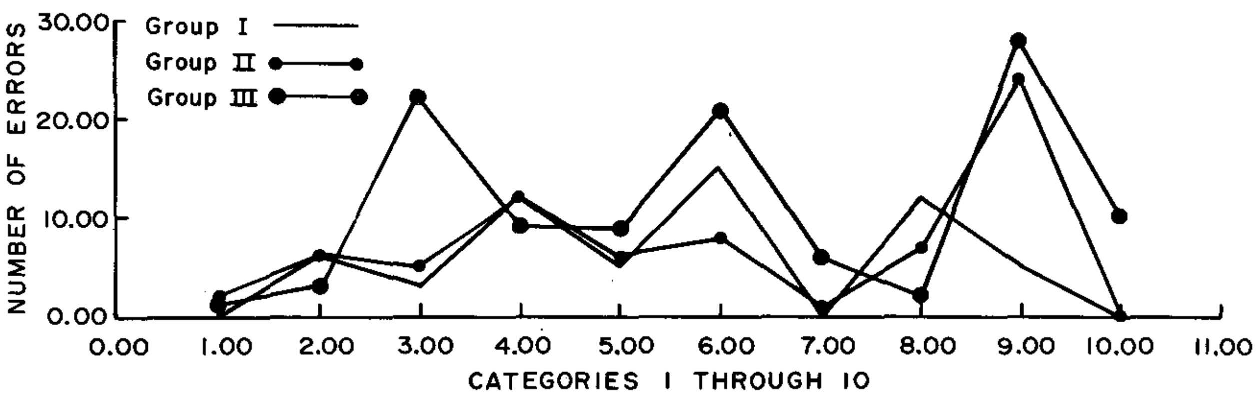


FIGURE 16. Errors by category (evaluation problem 2).

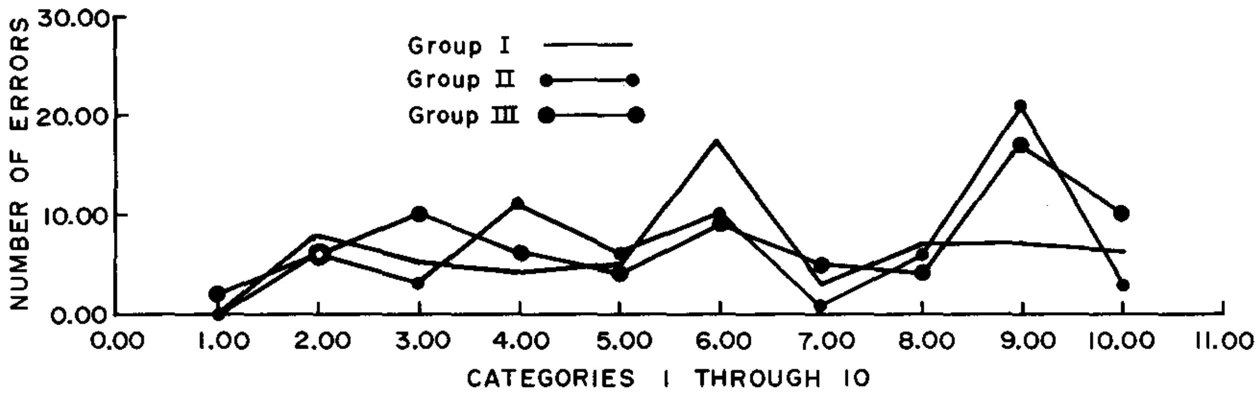


FIGURE 17. Errors by category (evaluation problem 3).

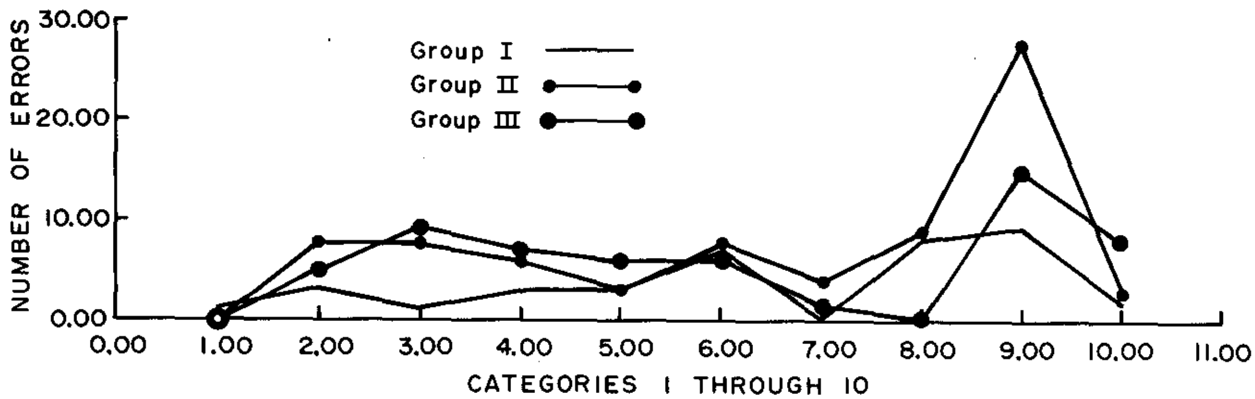


FIGURE 18. Errors by category (evaluation problem 4).

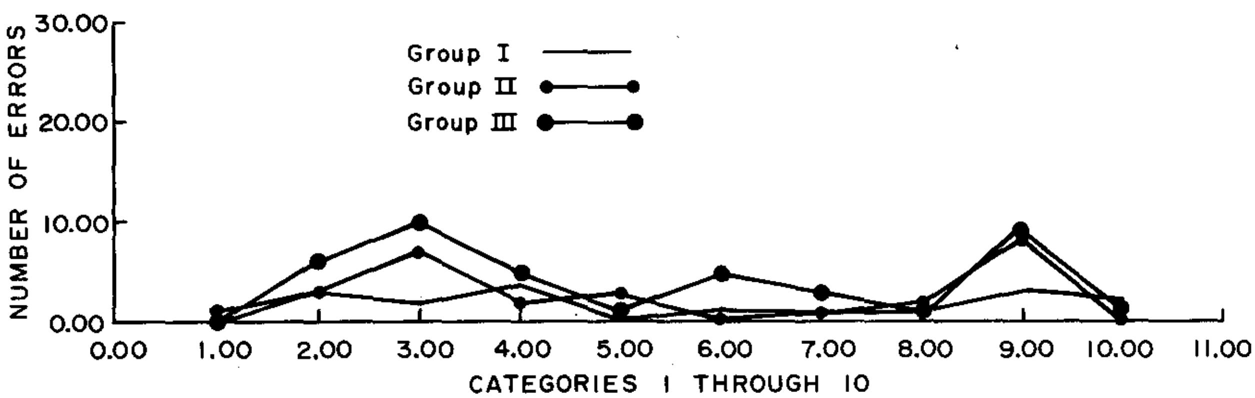


FIGURE 19. Errors by category (evaluation problem 5).

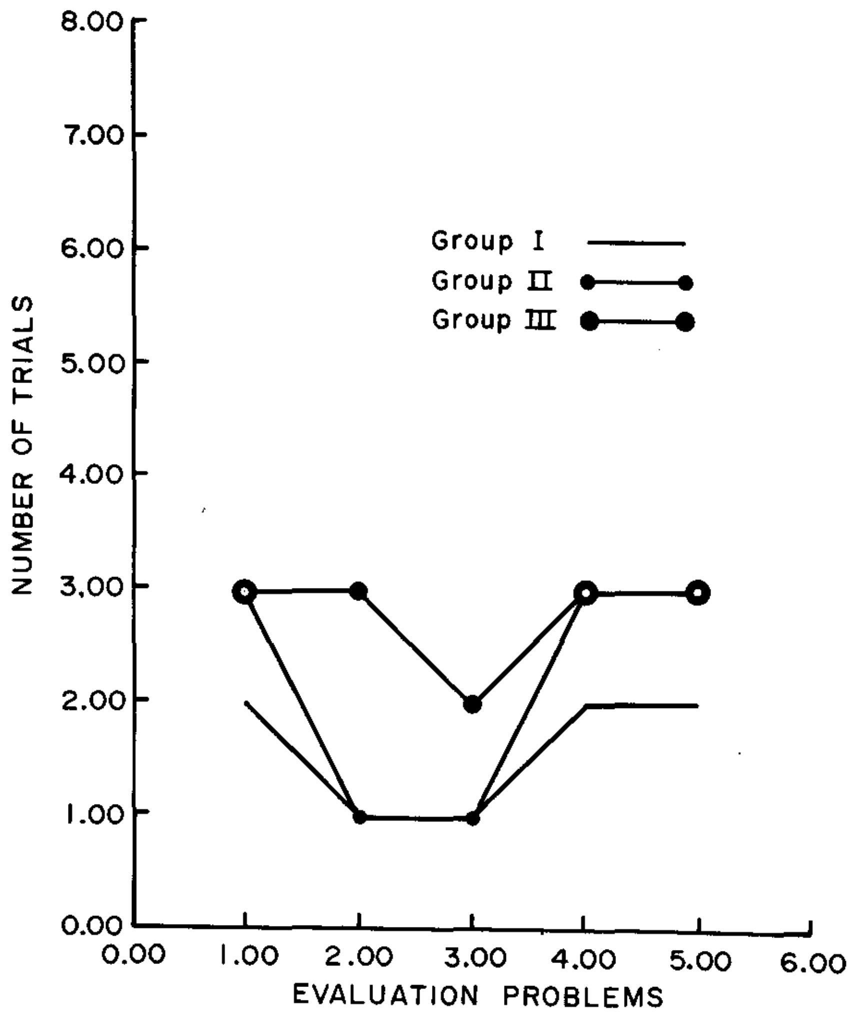


FIGURE 20. Number of trials on evaluation problems.

certain group and raw score performance. The remaining correlations of attempts, errors, and raw scores are low and demonstrate little significance.

B. Selection Test Analysis. The model presented in Table 11 demonstrates that, in combination, the Dial Reading and Directional Headings tests are very accurate in predicting performance on the pilot position (multiple R = 0.6921). Consequently, it is suggested that these two tests serve as a battery for selecting outside hires to operate the pilot position. The betas for the two tests in Table 11 are 0.4389 for the DRT and 0.2889 for the DHT. The suggested unit weights for the two tests, based on their betas, are 5 for the DRT and 3 for the DHT.

Table 15 demonstrates the utility of selection cut points of 200 for the community group and 150 for the handicapped group on the Dial Reading and Directional Headings composite score. Only four subjects from the community group whose raw score was at or below 40, scored above the cutoff on the composite. A lower cut point was assigned to the handicapped persons since a cut point of 200 eliminates five more of the handicapped than does the 150 cut point. Further, it can be noted that the mean performance of the subjects above the cut points is equivalent to the mean performance of the most proficient group, Group I. (See Table 15 and Figure 13.)

C. Practice Problems Evaluating Form. Item 1 in Table 12 shows that 63 percent of the subjects stated that the commands were taught very clearly, 36 percent stated that the commands were taught with average clarity, while only 1 percent stated that the commands (category 9) were taught unclearly. Item 2 of that same questionnaire states that 77 percent of the subjects felt that enough time was allowed for the dry runs. The responses in item 3 indicate that the verbal commands given during practice exercises could be improved but basically were understandable (62 percent), 30 percent said the commands were not easily understood, and 8 percent said the commands could not be understood. In item 4 the responses indicate that 64 percent felt that enough time was given in the practice exercises for entering messages while 35 percent felt that too much time was given.

D. Keyboard Evaluation Form. Table 13 indicates that the subjects felt the color scheme and the general keyboard setup were "helpful" to "very helpful." Fifty percent viewed the color scheme helpful, and 36 percent viewed the color scheme as very helpful, while 59 percent viewed the keyboard setup as helpful and 28 percent viewed the keyboard setup as very helpful. Suggested changes to the keyboard listed in items 18 and 19 (see Appendix 4) of the keyboard evaluation form were: (i) the DIR key should be moved nearer to the direction/numeric key pad since it is only used in conjunction with this key pad, (ii) the extra space key was not helpful and should be put to better use, and (iii) a DELETE key to correct inputs made on the function keys should be provided. At present it is impossible to delete an entire function since the DELETE key operates on one character at a time.

Table 15. Graphic Representation of Selection Cut Points

	Raw Scores	Selection Composite	Group	
	39	56	3	
	39	105	3	
	40	115	3	
	44	121	2	
Cut Point for	40	122	3	
Handicapped Group	30	140	3	150 Cut Point
Raw Score $\bar{X}$=44.42	40	169	3	
Cut Point for	48	175	2	200 Cut Point
Community Group	45	205	2	
Raw Score $\bar{X}$=45.12	40	209	3	
	40	210	3	
	42	214	2	
	44	227	2	
	43	247	2	
	44	260	3	
	48	268	2	
	43	274	3	
	42	279	1	
	47	289	2	
	43	291	3	
	47	294	1	
	47	310	2	
	43	327	1	
	40	347	1	
	48	360	1	
	41	369	1	
	48	372	2	
	43	400	2	
	48	406	1	
	46	411	2	
	49	451	1	
	49	453	1	
	48	476	1	
	47	499	1	

E. Multifactor Analyses of Variance. The ANOVA source table (Table 14) demonstrates only one significant independent effect, viz group membership. The Academy graduate group and the community group performed essentially the same; however, the latter had 72 hours of training as opposed to 40 hours of training for the Academy graduate group. Post hoc analyses showed that the handicapped group achieved proficiency with 88 hours of training but was significantly lower in performance than both Groups I and II. (See means for I, II, and III in Figures 12, 13, and 14.) The ANOVA shows that it made no difference in performance whether subjects were allowed to take notes or not, or whether they were given "long" or "short" academic preparation. There were no significant interaction effects between any of the three independent variables taken two at a time or three at a time.

F. Attempts, Errors, Raw Scores, and Number of Trials Across Evaluation Exercises and Command Categories. In Figure 12 the number of attempts steadily decremented from evaluation exercise 1 to 5. The largest number of attempts was made by Group II on evaluation exercise 1. The lowest number of attempts was made by Group III on evaluation exercise 5. These results could be interpreted in one of several ways. First, it could mean that since less time is allowed from evaluation exercise 1 to 5, there was less opportunity to make attempts. Second, it could mean that the inputs became more accurate. More than likely, the results reflect a combination of both opportunity and accuracy.

Errors on evaluation exercises also show a steady decrease from evaluation exercise 1 through 5. The largest number of errors was made by Group II on evaluation exercise 1. The smallest number of errors was made by Group I on evaluation exercise 5. Overall, Group I had the least errors across the evaluation exercises, Group II was second, and Group III was third in accuracy. (See Figure 13.)

Raw scores follow the same pattern as do errors, with Group I having the highest scores, Group II second highest, and Group III the lowest. (See Figure 13.)

The number of trials on evaluation exercises was largest for Group III, next largest for Group II, and smallest for Group I. It required about 40 hours of "hands on" training time for Group I, 72 hours for Group II, and about 88 hours for Group III. (See Table 16.)

Errors across all categories decreased from evaluation exercise 1 to 5. The largest number of errors was made on categories 2, 3, 6, and 9 by all three groups across all five evaluation exercises. It appears from viewing the evaluation exercise that categories 2 and 3 contain too many commands to be taught compared to the other command categories. There were 16 commands in category 2 and 10 in category 3. Items in categories 6 and 9 offer no clue as to why the commands were difficult. (See Figures 15, 16, 17, 18, and 19.)

It is concluded from the data on attempts, errors, raw scores, and number of trials across evaluation problems that Groups I, II, and III can all be trained to the proficiency level required to operate the RTF problems. The ratio of training time required in this study was about 2:1; i.e., it required approximately twice as long to train community and handicapped subjects to the required proficiency level. It seems reasonable to assume that more extensive training for the handicapped and community groups would result in a higher proficiency level than that achieved in this study. If Academy students are employed to operate the pilot position, each input would be trained only to a minimum level of proficiency because a new group of trainees would be trained every input.

Table 16. Training Time Required by Each Group

Groups	Hours in Training	Trials: Practice Problems	Trials: Evaluation Problems
I	40	16	8
II	72	24	11
III	88	17	14

G. Evaluation of Training System. All three groups met the training proficiency requirements for operating the pilot position within a reasonable length of time. Verbal statements from the FAA's National Aviation Facilities Experimental Center, Chicago-O'Hare Tower, and the Hull Center in Ottawa, Canada, indicate 8 to 12 weeks on the average for training time. The data from the present study support the feasibility of using computer-assisted instruction to teach the pilot position in much less time (see Table 16) than the reported training times where no programed instruction is employed. Therefore, we strongly recommend the use of computer-assisted training and evaluation for the pilot position. Using the computer to teach this position not only reduces training time, it also helps make maximum use of the computer system. Since the tasks involved in operating the ghost position, the Plan View Display (PVD), and the Data Entry and Display (DED) are so similar to the operation of the pilot position, it seems sensible to generalize the results of this study to the methods of teaching these other position keyboards also. Consequently, we further suggest that computer-assisted instruction be employed to teach these positions also. A functional description of a computer-assisted teaching method for keyboards is in Appendix 5.

Several problems were identified in the prototype pilot training system used in this study that need to be corrected before the system can be employed in computer-assisted training. The major problem was with the audio system. It was difficult to synchronize the computer timing mechanism with the audio output. The training system program provided a bell tone when the audio inputs were to be recorded; however, in the run mode the timing allowed by the computer for inputting was not consistent with the timing and the bell. Further, even if the bell had worked properly, it still would have been difficult to synchronize the audio with the computer timing mechanism. Another problem in the audio system was tone quality. The audio was not clear and the messages were sometimes difficult to understand.

A major software problem with the present training system was the setup for clearing the terminals. The sequential CRT clearing process required about 5 seconds. The person on the first terminal had 5 seconds longer to input the command message than did the person in the last position. A method for simultaneously clearing the terminals needs to be developed.

Computer-assisted instruction and evaluation have been successfully employed in many occupational fields. Routine tasks requiring the operation of machinery are especially adaptable to computer-assisted instruction. All three groups employed in this study performed well using this learning method. It would appear to be a valuable asset to the FAA Academy in terms of personnel utilization and maximum use of the computer to employ computer-assisted instruction in teaching the keyboard operations. This would be true without regard to whether handicapped persons, community persons, or Academy students were the trainees.

V. Summary of Recommendations.

A. Use of Academy Students Versus Use of Handicapped and Community Persons to Operate the Pilot Positions.

1. In the absence of any compelling financial or personnel reasons, it is suggested that community persons and handicapped persons be employed for the pilot positions.

2. If handicapped and community persons are hired, they should be qualified for selection on the basis of scores on the Dial Reading Test and Directional Headings Test. The composite of these two tests should be formed by weighting the Dial Reading Test 5 and the Directional Headings Test 3. Two different cut points should be used for community persons and handicapped. The recommended cut point for community people is 200. The recommended cut point for handicapped applicants is 150.

B. Use of a Computer-Assisted Training System.

1. A computer-assisted training system with programed instruction is strongly recommended for use in training persons to operate the pilot position, ghost position, and PVD and DEDS positions.

2. The prototype system used in this study should be implemented (see Appendix 5) for keyboard training within the structure of the present RTF system configuration.

3. An improved audio system should be developed that has better tone quality and a better means of synchronizing the computer operations with the audio outputs.

C. Changes to the Pilot Keyboard.

1. The DIR key should be moved nearer to the NUMERIC/DIRECTION keypad.

2. A DELETE key should be provided to correct erroneous function key entries.

3. A more profitable use should be made of the extra (green) space key.

D. Suggested Curricula Development.

1. Since the data demonstrated that there was no difference in performance between those who received "long" and those who received "short" academic training, it is recommended that only the minimal amount of academic preparation required to operate the position be provided, allowing more hands-on training time.

2. Since there was no difference in performance between those who took notes and those who did not, note taking should be optional.

3. Command categories number 2 and 3 should be broken up into smaller categories for instructional units.

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References

1. Federal Aviation Administration: RTF Engineering Requirements, ER-D-150-004, Washington, D.C., July 1976.

2. Henry, J. H.: Training of U.S. Air Traffic Controllers. Institute for Defense Analysis, Report R-206, Arlington, Virginia, January 1975.

Appendix 1

CATEGORY #1

Command 1. (Flight ID) STOP TURN (Heading FK Enter)
Command 2. (Flight ID) DISPLAY ALL FLIGHT PLAN DATA (Display FK Enter)
Command 3. (Flight ID) CONTACT Memphis CENTER ONE TWO NINER POINT ZERO
Kansas City CENTER ONE TWO SEVEN POINT ZERO
Albuquerque CENTER ONE TWO SIX POINT ZERO
(Frequency FK Enter)
Command 4. (Flight ID) CLEARED AS FILED (Depart FK Enter)
Command 5. (Flight ID) MAINTAIN PRESENT SPEED (Speed FK Enter)

CATEGORY #2

Command 1. (Flight ID) FLY HEADING TWO FIVE ZERO (Heading FK 250 Enter) (Headings are changed on dry runs)
Command 2. (Flight ID) MAINTAIN ONE FOUR THOUSAND (Altitude FK 140 Enter) (Altitudes are changed on dry runs)
Command 3. (Flight ID) REDUCE SPEED TO TWO FOUR ZERO KNOTS (Speed FK 240 Enter) (Speeds are changed on dry runs)
Command 4. (Flight ID) REDUCE TO HOLDING SPEED (Speed FK H Enter)
Command 5. (Flight ID) RESUME NORMAL SPEED (Speed FK RZM Enter)
Command 6. (Flight ID) FLY RUNWAY HEADING (Heading FK R Enter)
Command 7. (Flight ID) IDENT (Beacon FK I Enter)
Command 8. (Flight ID) TURN RIGHT (Heading FK → Enter) (Right has been interchanged with left on dry runs)
Command 9. (Flight ID) REDUCE TO APPROACH SPEED (Speed FK A Enter)
Command 10. (Flight ID) CLEARED VIA LAST ROUTING CLEARED (Route FK RZM Enter)
Command 11. (Flight ID) SQUAWK ALTITUDE (Beacon FK A Enter)
STANDBY (Beacon FK S Enter) (Altitude has been interchanged with standby on dry runs)
Command 12. (Flight ID) INTERCEPT FLIGHT PLAN ROUTE (Route FK ⇉ Enter)
Command 13. (Flight ID) CLEARED FOR NDB APPROACH (Approach FK N Enter)
VOR APPROACH (Approach FK V Enter)
ILS APPROACH (Approach FK I Enter)
Command 14. (Flight ID) CLEARED TO TULSA (Clearance Limit FK TUL Enter)
McALESTER (Clearance Limit FK MLC Enter) (TUL and MLC are interchanged on dry runs)
Command 15. (Flight ID) EXPEDITE TURN (Heading FK Max Key Enter)
Command 16. (Flight ID) SQUAWK TWO FIVE ZERO TWO (Beacon FK 2502 Enter)

CATEGORY #3

Command 1. (Flight ID) TURN RIGHT HEADING THREE SIX ZERO (Heading FK → 360 Enter) (Right and left are interchanged and headings are changed on the dry runs)

(Appendix 1 continued on following page)--

Command 2. (Flight ID) CLIMB AT PILOT'S DISCRETION MAINTAIN FLIGHT LEVEL TWO TWO ZERO (Altitude FK MINI 220 Enter) (Climb and descend are interchanged and flight levels are changed on the dry runs)

Command 3. (Flight ID) CRUISE ONE ONE THOUSAND (Altitude FK 110 CRZ Enter) (Altitudes are changed on the dry runs)

Command 4. (Flight ID) DESCEND IMMEDIATELY MAINTAIN SIX THOUSAND (Altitude FK MAX 60 Enter) (Altitudes are changed on the dry runs)

Command 5. (Flight ID) CLEARED FOR ILS STRAIGHT IN APPROACH (Approach FK I (or V) S Enter) (ILS and VOR are interchanged on the dry runs)

Command 6. (Flight ID) SQUAWK TWO TWO ZERO ZERO AND IDENT (Beacon FK 2200 I Enter) (Beacon codes are changed on the dry runs)

Command 7. (Flight ID) REPORT REACHING ONE SEVEN THOUSAND (Report FK R (or L) 170 Enter) (Reaching and leaving are interchanged and altitudes are changed on the dry runs)

Command 8. (Flight ID) CLEARANCE VOID IF NOT OFF GROUND BY ONE FOUR THREE ZERO (Depart FK > 1430 Enter) (Times are changed on dry runs)

Command 9. (Flight ID) TURN FORTY DEGREES RIGHT (Heading FK 40 → Enter) (Right and left are interchanged and headings are changed on the dry runs)

Command 10. (Flight ID) RADAR CONTACT (LOST) (Report FK R C (or L) Enter) (Radar contact and radar contact lost are interchanged on the dry runs)

CATEGORY #4

Command 1. (Flight ID) MAINTAIN PRESENT HEADING UNTIL REACHING ONE ONE THOUSAND (Heading FK / Altitude FK 110 Enter) (Altitudes are changed on the dry runs)

Command 2. (Flight ID) CONTACT Tulsa approach ONE ONE NINER POINT TWO AT Mayes (Freq FK @ FRD FK Mayes Enter) (Tulsa approach and Mayes are interchanged with these: Memphis Center, Miami; and Fort Worth Center, McAlester on the dry runs)

Command 3. (Flight ID) CLEARED FOR BOLDE ONE DEPARTURE (Depart FK (SID) Bolde 1 Enter)

Command 4. (Flight ID) MAINTAIN HEADING ONE FIVE ZERO UNTIL TWO TWO ONE TWO (Heading FK 150 / 2212 Enter) (Headings and times are changed in the dry runs)

Command 5. (Flight ID) DESCEND AND MAINTAIN FLIGHT LEVEL TWO EIGHT ZERO AT TWO ONE THREE ZERO (Altitude FK 280 @ 2130 Enter) (Climb and descend are interchanged and the times and altitudes are changed in the dry runs)

(Appendix 1 continued on following page)--

CATEGORY #5

Command 1. (Flight ID) MAINTAIN HEADING ZERO NINER ZERO UNTIL REACHING ONE TWO THOUSAND (Heading FK 090 / Altitude FK 120 Enter) (Altitudes and headings are changed on the dry runs)

Command 2. (Flight ID) MAINTAIN TWO TWO ZERO KNOTS UNTIL TULSA (Speed FK 220 / FRD FK Tul Enter) (Speed has changed and Tulsa has been interchanged with Miami in the dry runs)

Command 3. (Flight ID) DEPART MIAMI HEADING THREE SIX ZERO (Depart FK FRD FK MIO Heading FK 360 Enter) (Miami has been interchanged with Tulsa and the headings have been changed on the dry runs)

CATEGORY #6

Command 1. (Flight ID) CLEARED TO McALESTER HOLD NORTH LEFT TURNS (Clearance Limit FK MLC Hold FK Dir Key N ← Enter) (McAlester has been interchanged with Tulsa and Miami and the directions and left and right have been changed on the dry runs)

Command 2. (Flight ID) FLY HEADING ONE EIGHT ZERO UNTIL REACHING ONE TWO THOUSAND BEFORE PROCEEDING ON COURSE (Heading 180 / Altitude FK 120 RZM Enter) (Headings and altitudes have been changed on dry runs)

CATEGORY #7

Command 1. (Flight ID) CLEARED VIA BOLDE ONE DEPARTURE SPRINGFIELD TRANSITION (Depart FK (SID) Bolde 1 T SGF Enter) (Springfield is interchanged with Fort Smith on dry runs)

Command 2. (Flight ID) HOLD SOUTH OF MIAMI ON THE ONE EIGHT ZERO RADIAL TWO MINUTE LEGS (Hold FK Dir Key S FRD FK MIO 2 Min Enter) (Direction and minutes have been changed and Miami has been interchanged with McAlester and Tulsa on the dry runs)

CATEGORY #8

Command 1. (Flight ID) CROSS TULSA AT ONE ONE THOUSAND CLEARED FOR VOR APPROACH (Altitude FK X FRD TUL @ 110 Approach FK V Enter) (Altitudes are changed and TUL in interchanged with MLC and MIO on the dry runs.)

CATEGORY #9

Command 1. (Flight ID) CLEARED FOR TULSA ONE ARRIVAL CROSS TULSA AT OR ABOVE ONE THREE THOUSAND (Route FK (STAR) TULSA1 X FRD RK TUL ↑ Altitude FK 130 Enter) (Altitudes are changed on the dry runs)

Command 2. (Flight ID) CLEARED VIA BOLDE ONE DEPARTURE CROSS INOLA AT OR BELOW SEVEN THOUSAND (Depart FK (SID) Bolde 1 X FRD FK INOLA ↓ Altitude FK 70 Enter) (Inola has been interchanged with Flint and Bolde and altitudes have been changed on dry runs)

(Appendix 1 continued on following page)--

CATEGORY #10

Command 1. (Flight ID) HOLD EAST OF MIAMI ON VICTOR TWO THREE MINUTE LEGS RIGHT TURNS (Hold FK Dir Key E FRD FK MIO V2 3 Min → Enter) (Victor #s, times, directions, places, and right or left have been changed on the dry runs)

Command 2. (Flight ID) CROSS VICTOR THREE TWO ZERO MILES EAST OF TULSA (Route FK X V3 20 miles Dir Key E FRD FK TUL Enter) (Victor #s, directions, and places have been changed on dry runs)

Appendix 2

BIOGRAPHICAL QUESTIONNAIRE

All the items which follow are in the familiar multiple choice format. Answer each one by blackening the circle in the appropriate column (A, B, C, D, or E) on your answer sheet. Choose the response that best fits you and only make one response per question.

HIGH SCHOOL EDUCATION

1. Which of the following best describes your high school career?

    A. Did not attend high school
    B. Did not complete high school
    C. High school diploma granted by school
    D. High school diploma granted by G.E.D.

2. How old were you when you left high school?

    A. 15 or younger
    B. 16
    C. 17
    D. 18
    E. 19 or older

What grades, on the average, did you get in the following high school courses? Fill in the letter corresponding to the grade for each subject.

    A. About "A-" to "A+"
    B. About "B-" to "B+"
    C. About "C-" to "C+"
    D. Lower than "C-"
    E. Did not have course

3. Arithmetic, Math

4. Physical Science

5. Biological Science

6. English

7. Social Studies

(Appendix 2 continued on following page)--

8. Business or Commercial

9. Physical Education

10. Vocational or Agricultural

11. What was your overall high school average?

12. When you were growing up, about how many books were around the house?

    A. A large library
    B. Several bookcases full
    C. One bookcase full
    D. A shelf full
    E. Very few or none

13. While in high school, how <u>many</u> of the following positions did you hold?

    Chairperson of an important student committee
    Cheerleader
    Class officer
    Editor of a publication
    Leading actor in a play
    Member of the student council
    Member of the debating team
    President of an honorary scholastic organization
    Speaker at the class commencement
    Captain of an athletic team
    President of a student club

    A. 0 to 2
    B. 3 or 4
    C. 5 or 6
    D. 7 or 8
    E. 9 to 11

14. Relative to your close friends, how well did you do in physical or athletic activities in high school?

    A. Much better than they did
    B. Somewhat better than they did
    C. About as well as they did
    D. Not quite as well as they did
    E. Not nearly as well as they did

(Appendix 2 continued on following page)--

15. In high school, when friends came to you with their personal problems, how likely were you to go out of your way to give them help or advice?

   A. Much more likely than most people
   B. Somewhat more likely than most people
   C. About as likely as others
   D. Somewhat less likely than most people
   E. Much less likely than most people

16. Before or during high school, did you ever conduct a scientific experiment on your own initiative (not as part of any required school assignment)?

   A. No
   B. Yes-both before and during high school
   C. Yes-before high school
   D. Yes-during high school

EDUCATION BEYOND HIGH SCHOOL

17. Which of the following best describes your educational background?

   A. No formal education beyond high school
   B. Attended college but did not receive a degree
   C. Attended college and received a degree
   D. Have done college graduate work, but did not receive a degree beyond a bachelor
   E. Have an advanced degree (M.S., M.A., Ph.D., etc.)

18. How long has it been since you last attended school as a full time student?

   A. Less than a year
   B. 1-2 years
   C. 2-3 years
   D. 3-4 years
   E. Over 4 years

From the following three questions, answer the one that is appropriate, either item 19, 20, or 21.

What was your major area of study in college?

(Appendix 2 continued on following page)--

19. A. Did not attend college
    B. Dramatic Arts
    C. Languages
    D. Humanities
    E. Biological Science

20. A. Physical Science
    B. Social Science
    C. Applied Studies (Agriculture)
    D. Applied Studies (Business)
    E. Applied Studies (Education)

21. A. Applied Studies (Home Economics)
    B. Applied Studies (Speech, Journalism)
    C. Applied Studies (Professional)
    D. Double Major
    E. Other

22. Before appointment as an ATC specialist how often had you flown in an airplane?

    A. Very often
    B. Often
    C. Sometimes
    D. Seldom
    E. Never

23. Before appointment as an ATC specialist how much time had you spent around airports?

    A. Very much
    B. Much
    C. Some
    D. Little
    E. Very little

MILITARY EXPERIENCE

24. Do you have prior military experience?

    A. No (if no, skip #25)   B. Yes

25. Which branch of the service?

    A. USAF
    B. USN
    C. USMC
    D. USA
    E. USCG

(Appendix 2 continued on following page)--

26. Do you have a prior control tower operator (CTO) rating?

A. No
B. Yes-IFR
C. Yes-VFR
D. Yes-both IFR and VFR

27. Do you have a prior air traffic control specialist rating?

A. No
B. Yes-Center
C. Yes-Flight Service Station (FSS)
D. Yes-both Center and FSS

28. Do you have prior IFR operation experience?

A. No
B. Yes-military
C. Yes-civilian
D. Yes-military and civilian

For the following types of IFR, approximate the amount of experience you had using the following scale:

A = None
B = Under 6 months
C = 6 to 12 months
D = 12 to 18 months
E = Over 18 months

29. ARTCC

30. RATCC or CATCC

31. ARAC

32. RAPCON

33. TOWER

34. GCA (RADAR)

35. GCI (RADAR)

36. Have you had prior VFR operations experience?

(Appendix 2 continued on following page)--

A. No
B. Yes-military
C. Yes-civilian
D. Yes-military and civilian

Use the following scale to describe the amount of VFR operations experience you have had for the types listed below.

A = None
B = Under 6 months
C = 6 to 12 months
D = 12 to 18 months
E = Over 18 months

37. Tower

38. FSS or IFSS

39. GCI (nonradar)

Use the scale below to list the prior communications operations experience you have had for the items below.

A = None
B = Restricted rating
C = 3rd class rating
D = 2nd class rating
E = 1st class rating

40. Station

41. Ground to air

42. Point to point

PRIOR AIRMAN CERTIFICATE

For the following types of certificates or ratings, use the scales below to indicate whether or not you have the certificate and if it is based on military and/or civilian experience.

A = No certificate or rating
B = Military experience
C = Civilian experience
D = Both military and civilian

43. Airline transport

44. Commercial

45. Private

46. Flight Instructor

47. Ground Instructor

(Appendix 2 continued on following page)--

48. Dispatch-air carrier

49. Navigator/bombardier

50. Single-engine jet

51. Single-engine turbo prop

52. Single-engine reciprocating

53. Multi-engine jet

54. Multi-engine turbo prop

55. Multi-engine reciprocating

56. Instrument

57. Rotorcraft

58. Glider

59. Prior to Phase I indoctrination, what type of air traffic control experience/training have you had with FAA?

    A. FSS
    B. Terminal
    C. En Route
    D. Predevelopmental or other FAA preparatory training
    E. None

60. Prior to Phase I indoctrination, how long have you been in the 2152 option?

    A. Was not in 2152 option prior to Phase I indoctrination
    B. Less than 1 year
    C. 1-2 years
    D. 3-4 years
    E. 5 years or more

Appendix 3

PILOT STUDY

Evaluation Form for Practice Modules.

Directions: Circle the response that best expresses your observation or make comments, where appropriate.

1. Were the commands taught clearly?

1	3	5
unclear	average clear	very clear

2. Was enough practice time given? (Dry runs)

1	3	5
not enough	enough	too much

3. Were the verbal commands given during the practice exercise understandable? (the cassette recordings)

1	3	5
not understandable	understandable	easily understood

4. Was the timing of the commands in the practice exercise spaced appropriately?

1	3	5
not enough time given	enough time given	too much time given

5. Did you note any possible errors in the commands given during the practice exercise? (Please list errors below.)

6. Feel free to make any comments or suggestions that you think would improve the methods employed in this practice module.

Comments or Suggestions:

Appendix 4

PILOT STUDY EVALUATION FOR KEYBOARD

Circle the response that best expresses your observations or make comments where appropriate.

1. Did you find the color scheme helpful in locating the keys?

1	2	3	4
Not Helpful	Helpful	Very Helpful	No Difference

2. What is your impression of how the keyboard is set up in regard to:

	Not Helpful	Helpful	Very Helpful
Flight ID Keys (orange)	1	2	3
Function Keys (blue)	1	2	3
Action Keys (dark grey)	1	2	3
Display Keys (green)	1	2	3
Alpha Keys (light grey)	1	2	3
Entry Keys (black)	1	2	3
Numeric/Direction Keys (yellow)	1	2	3

3. Do you think that the ALPHA keys would be more efficient if they were arranged in the same order as on a typewriter?

1	2	3	4
No	Maybe	Yes	No Difference

4. Do you think that the NUMERIC/DIRECTION keys would be more efficient if they were arranged in the same order as on a ten-key adding machine?

1	2	3	4
No	Maybe	Yes	No Difference

(Appendix 4 continued on following page)--

5. Which do you feel would be the best arrangement for the FLIGHT ID keys?

IN ORDER		ALTERNATED	
1	7	1	2
2	8	3	4
3	9	5	6
4	A	7	8
5	B	9	A
6	C	B	C

6. Did you use one hand (which one) or both?

LEFT	RIGHT	BOTH
none	none	none
25%	25%	25%
50%	50%	50%
75%	75%	75%
100%	100%	100%

7. Do you think it would be helpful if the ACTION keys were positioned on the right side and the ALPHA keys were positioned on the left side?

1	2	3	4
Not Helpful	Helpful	Very Helpful	No Difference

8. Do you think the position of the ENTER key is best where it is?

1	2	3
Better Somewhere Else (Where?)	No Difference	Best There

9. Do you think the FUNCTION keys are better at the bottom or the top of the keyboard?

1	2	3
Bottom	Top	Better Somewhere Else (Where?)

10. Was it helpful having two SPACE keys?

1	2	3	4
Not Helpful	Helpful	Very Helpful	No Difference

11. Did the non-functional keys:

	No	Sometimes	Yes	No Difference
Cause you to make mistakes?	1	2	3	4
Slow you down?	1	2	3	4

(Appendix 4 continued on following page)--

12. Do you think that the CARRIAGE RETURN key should be moved?

1	2	3
No	Yes	No Difference

13. Would it be helpful to have the ACTION keys further apart?

1	2	3	4
Not Helpful	Helpful	Very Helpful	No Difference

14. Is it confusing having the MIN ("), MINI, and MAX ACTION keys right next to each other?

1	2	3	4
No	Sometimes	Yes	No Difference

15. Were the ENTRY keys helpful in correcting your mistakes?

1	2	3	4
Not Helpful	Helpful	Very Helpful	No Difference

16. Which of the following keys did you use to correct mistakes?

	Never	Rarely	Sometimes	Mostly	Always
Delete Character	1	2	3	4	5
Delete Line	1	2	3	4	5
Clear Display	1	2	3	4	5

17. Would it be helpful to have the DIR ACTION key closer to the NUMERIC/DIRECTION keys?

1	2	3	4
Not Helpful	Helpful	Very Helpful	No Difference

18. What was your impression as to the way the keyboard was broken up into FLIGHT ID, FUNCTION, ACTION, DISPLAY, ALPHA, ENTRY, and NUMERIC/DIRECTION segments? Could it be done better? How?

19. How could the keyboard be made more efficient?

Appendix 5

PROPOSED PILOT TRAINING MODEL

Introduction.

The cost of pilot training involves both human resources required to do training and use of computer equipment. To minimize the cost, both computer equipment and training personnel must be effectively used. The subsequent description outlines a model that can be used for pilot training, hopefully without a major reconfiguring of the hardware in the present system. Perhaps all that is needed is software stored on an RK06 disk pack. The training could take place on second or third shift since equipment will be available. The model would be applicable and appropriate with either professional pilots or Academy students.

Model.

Training programs are systematic procedures for helping people learn skills, rules, or concepts that they can apply to their job situation. Learning is usually defined as a relatively permanent change in thought or action that results from practice or experience.

The principles we are most concerned with in the pilot trainee situation have to do with feedback and reinforcement. Feedback of knowledge to the trainee on the results of his/her behavior has strong reinforcement properties. Most people find "rewarding" the knowledge that they have done well and "negatively reinforcing" the knowledge that they have done poorly. This should serve to promote learning of behavior that was judged "good" and extinction of that judged "poor." If a person is to learn to respond correctly he/she must have some way of knowing what is and what isn't within the acceptable limits. Feedback gives this knowledge.

Negative reinforcement may have some useful purpose in training. On the other hand, it is doubtful that it can serve usefully as the only means of shaping behavior. If negative reinforcement is used, it should be used in conjunction with opportunities for positive reinforcement. That is, if an incorrect response is criticized, it should be done in a fashion that encourages the trainee to adopt a more appropriate mode of behavior for which he/she can then be rewarded.

Timing of feedback is of extreme importance. This is mainly because delays increase the chances that some other response will be reinforced, and the trainee will lose direction and become confused. The last thing he/she does is the most likely to be reinforced and remembered without regard to whether it be correct or incorrect. Conditioning occurs most rapidly when the to-be-learned response is followed immediately by feedback on the correctness of the response. This is termed shaping. Shaping is similar to a guidance system that continually adjusts or steers the learner toward the desired behavior and consequently must occur immediately following the behavior.

In general this principle says that knowledge of results is a good thing, and that the sooner it comes after the learner's response, the better. So it would be most beneficial if the pilot training system were designed to provide the pilot trainee with immediate rewarding feedback when he/she makes a correct response and feedback that will shape/direct the trainee toward the desired goal when he/she makes an incorrect response. The opportunity should be given to correct any error immediately after it is made, since the last response made will be the one most likely to be remembered and the one toward which direct subsequent behavior will be directed. A pilot training system of this sort is illustrated by the flow chart shown at the end of this appendix.

Explanation of Flow Chart.

The parameters are specified off-line in building the operating program. Parameters are the characteristics or values used to determine an event. The stimulus input file is an independent data file that contains the list of recorded messages the pilot trainee will hear and be required to enter on the CRT. The stimulus input files are built independently and are coded or named. First, the stimulus input file code or name is input as a parameter to the operating program. Second, a parameter is required in the operating program to establish a latency period. A latency period is the amount of time allowed for the pilot trainee to respond to the recorded message he/she receives. Third, the maximum number of incorrect responses allowable before an error is recorded must also be established as a parameter in the operating program. The fourth and last parameter to be specified is the number of sequentially correct responses the student must make before he/she is considered to be proficient in operating the pilot position.

Once the parameters have been specified, the operating program task file is built and will run in the manner shown on the flow chart. The flow chart demonstrates schematically the steps or general flow of the program.

When the program starts, the pilot trainee will receive the stimulus, a prerecorded message. (This list of prerecorded messages is exactly matched with the list of messages in the stimulus input file that was selected as a parameter.) If possible, the audio system should coordinate with the messages in the stimulus input file through the microprocessor. This would lessen problems with the synchronization of the prerecorded messages and the stimulus input file. A cassette should be used for these recordings for convenience in handling and storage. Another option is individually operated cassette players, since some pilot trainees will be able to enter the messages more accurately than others, and some will make errors that would slow everyone using the same recording. These cassette players should be modified so the stimulus messages can be heard through the headsets. Also, it would be helpful if the cassette players had both hand and foot controls for starting or stopping the tape and moving the tape forward or backward. The foot control would allow the hands to remain free to enter the messages quickly. However, hand control will be necessary for the handicapped who are unable to use a foot control. The trainee must respond to the recorded message by entering the message on the CRT in the proper format and using the correct symbols and characters. The operating program then performs a "compare" to determine if the response was correct or incorrect. If the response was correct, there will be a reward in the form of a message displayed on the CRT, "Your response was correct."

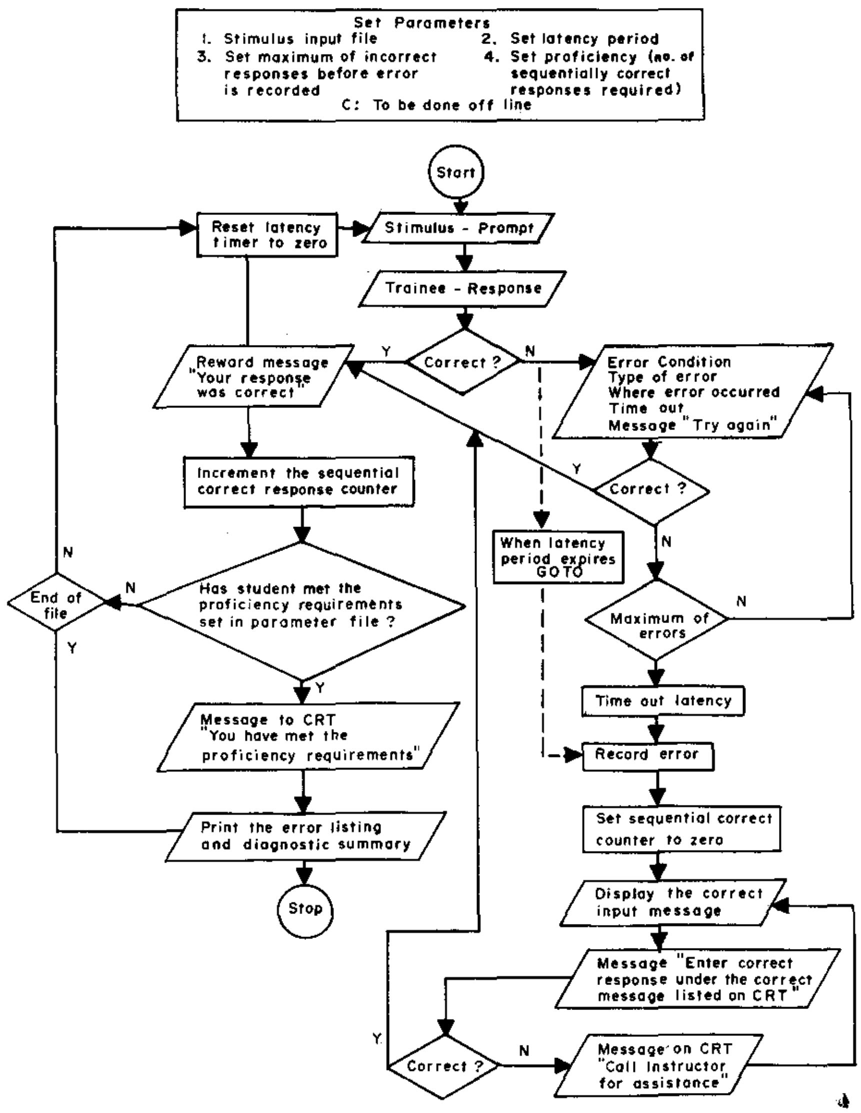
Following the reward, the sequential correct response counter will be incremented. In the next step the operating program performs another "compare" between the sequential correct response counter and the proficiency parameter to determine if the proficiency requirements have been met. If the trainee has achieved proficiency, a message will be displayed on the CRT, "You have met the proficiency requirements." Then, a listing of the errors the trainee incurred prior to reaching proficiency and a diagnostic summary will be printed on the printer. At this point the program terminates.

If the trainee makes a correct response but the proficiency requirements have not been met, there will be a check for the end-of-file. If it is not the end-of-file, the latency timer will be reset to zero and there will be another stimulus prompt. If it is the end-of-file, the error listing and diagnostic summary will be printed on the printer and the program will stop.

When a pilot trainee receives a stimulus and his/her response is incorrect, the program will go to an error condition. The operating program will determine the type of error and where the error occurred in the input. The message displayed on the CRT will be "Try again." If, on the second try, the response is correct, the reward message will follow and the program will proceed as previously described when no error was made. If the response continues to be incorrect, the "Try again" message will continue to be displayed until the maximum number of allowable incorrect responses set as a parameter has been met. Once the maximum number of errors has been reached or the latency period times out, the exact error will be recorded on the error file and the diagnostic file, the sequential correct counter will be set to zero, and the correct input message will be displayed on the CRT with a message telling the trainee to enter the correct response under the corrected message listed on the CRT. If the correct response is entered, a reward message will follow and the program will continue the same as when the initial input was correct. If again the response is not correct, the message displayed on the CRT will be "Call the instructor for assistance." Again, the correct input message will be displayed, and the trainee must enter the correct message. This will be a continuous loop until the correct response is entered. When the correct response is entered, a reward message will follow and the program will continue as before.

If the pilot trainee receives a stimulus and does not respond within the time limit specified in the parameters, the program will go directly to the error and diagnostic file, the sequential correct counter will be set to zero, and the program will continue as described when an incorrect response is made.

The error listing output at the termination of the program is just a simple chronological listing of the exact errors made. The diagnostic output consists of a summary or frequency distribution of the types of errors committed, indicating the apparent types of messages where remedial work is needed. Practice stimulus input files could then be built and used on the same operating program where stimulus input messages of a certain type are heavily emphasized.



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