THE USE OF A PART-TASK AIR INTERCEPT TRAINER IN F-16 AIRCREW TRAINING: RESEARCH RESULTS

George F. Lahey
David C. Hubbard
University of Dayton Research Institute
Dayton, Ohio

Bernell J. Edwards
Operations Training Division
Air Force Human Resources Laboratory
Williams Air Force Base, AZ

ABSTRACT

A training research program was initiated by the Air Force in 1984 to study applications of microcomputer technology to aircrew training. Emphasis was placed on the development of a methodology for identifying opportunities for part-task trainer applications and on demonstrations of the potential of part-task trainers built around microprocessor technology. Out of that program a number of part-task trainers have been developed and are being used to support pilot training programs. The most recent of these, the Air Intercept Trainer (AIT), is a low-cost, high fidelity, classroom device used for training F-16 air-to-air intercept skills. The intercept performance of experienced pilots converting from the F-106 to the F-16 who trained on the AIT was compared to the performance of others using classroom procedures. The AIT is described briefly and the results of the experiment are presented.

INTRODUCTION

The Air Intercept Trainer (AIT) provides a dynamic simulation of F-16 Head-Up Display and Radar Electro-Optical Display (HUD/REO) images in near real time. Ownship maneuver capabilities are provided using F-16 throttle and stick controllers as input devices. The dynamic effects of ownship maneuvers and target relative motion for single targets or for multiple targets, each with its own heading, altitude, and airspeed, are presented. The AIT was developed by the Link Flight Simulation Division of the Singer Company under contract to the Operations Training Division, Air Force Human Resources Laboratory, Williams AFB. The system input and output are managed by the 68020 microprocessor of a Motorola VME2000 computer programmed in Fortran. The HUD/REO displays are presented on commercially available CRTs. A photograph of the AIT is presented in Figure 1.

Figure 1. Air Intercept Trainer

The AIT incorporates an integrated Instructor/Operator Station (IOS) from which the instructor controls the intercept scenarios presented to the student. The IOS provides keyboard entry for menu selection of scenarios, the ability to freeze and unfreeze motion, and a display to present plan and gods-eye views of the intercept, that can be used for monitoring the intercept as well as for training purposes.

Target data can be presented on the radar in either freeze mode, in which both the target and ownship are frozen in space, or in dynamic mode, in which the targets move at constant speed on a constant heading. Individual exercises start with the system in the freeze mode. The instructor then controls system function by unfreezing or freezing the targets at any time during the intercept for instructional purposes. After target detection, the intercepts can be run in either flyable or nonflyable intercept modes. In flyable mode, ownship remains on freeze until lock-on, then is 'flown' by the student through the rest of the intercept. In the nonflyable mode, ownship stays on freeze to lock-on, then the computer takes over and runs a 1V1 intercept using an algorithm that reads the target's range, altitude and aspect angle and controls ownship accordingly.

Background

The initial model of the AIT was installed for research and demonstration purposes at the Arizona Air National Guard (AZ ANG) facility in Tucson. The initial model, located at Tucson throughout the research period, was nonflyable in that it had fixed throttle and stick settings. Only the radar control switches were active. Thus, while the student could operate the system for detection, all intercepts run in Tucson were run under computer control. In the second model, maintained at Williams AFB during the course of this research, the throttle and stick were active, so that intercepts could be run under either student control or computer control. A

repertoire of 26 scenarios using from one to five of 67 preprogrammed targets was included in the software delivered with the trainer.

The AZ ANG uses the trainer in three one-hour lessons to teach: interpretation of the HUD/REO symbology and switchology (all throttle and stick switches are completely functional), use of the radar and HUD for target detection, and intercept management. Prior to initiation of the experiment described herein, student use of the AIT in these lessons was observed over a period of several months. The objective was to determine how best to measure the performance of the subjects. A scoring system based on a model of an idealized intercept was developed. The scoring system could be used for grading inter- cepts in both the AIT and the Operational Flight Trainer (OFT) being used to prepare the subjects for their first intercept ride in the F-16. The scoring system could not be developed in time to provide scoring on the AIT, however, so it was incorporated in the OFT. Thus, the effect of the AIT training could be measured on the basis of transfer of training to the OFT.

APPROACH

The subjects for this experiment were experienced Air National Guard pilots in training in Tucson for conversion from flying the F-106 to flying the F-16. All pilots had prior intercept training and experience. The majority of the pilots were part-time Guard personnel, several with airline experience. Their military flight experience ranged from a low of just under 1000 hours to a high of over 7,000 hours. At the point of gathering the transfer data, all subjects had completed roughly four weeks of F-16 conversion training in Tucson and had had at least six training flights in the aircraft. The training program included a mixture of group lectures, self-paced slide-tape lessons, and one-on-one supervised part-task trainer use, plus conversion flights in an F-16B.

Because this was a field research opportunity in which the researchers were responsible to interfere with the training process as little as possible, the researchers did not exercise control of the syllabus, the content of the written materials used in the academic portions of the training, the selection of IPs for different training events, or the communications of instructors during lectures and during use of the AIT.

Procedure

Subjects were randomly assigned to one of four experimental groups prior to receiving any training on the AIT. All subjects then received symbology and switchology training on the AIT (AZ ANG Lesson HR-2). Following the switchology lesson, subjects in Group 1 had no further AIT training, but received a one-hour lecture on target detection, followed by a second one-hour lecture on intercepts in which they previewed videotaped sequences showing the eight research intercepts. Subjects in Groups 2, 3 and 4 received two supervised one-hour lessons on the AIT at Tucson in nonflyable mode, one on detecting targets (HR-3), and the second on running intercepts (HR-4).

After their initial intercept training, all subjects went to Williams AFB from Tucson to participate in the research. Upon arrival at Williams AFB, subjects in Groups 1 and 2 were briefed on the research procedures, then went directly to the OFT (the Training Effectiveness Research Facility (TERF) at Williams AFB) to run a series of eight research intercepts. Subjects in Groups 3 and 4 had additional supervised intercept training (approximately one hour) in the AIT on arriving at Williams AFB before running the research intercepts. Subjects in Group 3 got the additional training in nonflyable mode. Subjects in Group 4 got the additional training in flyable mode.

The number of subjects available was limited by the class size (13 subjects) and the number of classes (3) in the F-106 to F-16 conversion training program during FY 87. Four of the available subjects were dropped from the experiment; one because of an extremely negative attitude toward the research, one because he had been deliberately placed in Group 4 because of poor performance during the earlier parts of his training, and two because they lacked the prerequisite symbology recognition skills. The resultant group sizes were ten subjects in Group 1, nine subjects in Group 2, seven subjects in Group 3, and nine subjects in Group 4.

Measurement

Training effectiveness was measured by comparing the performance of the subjects during intercepts run in the TERF. All subjects ran the same eight intercepts in sequence in the TERF, with no feedback given until completion of the last intercept. The first intercept was a straight through intercept. The remaining intercepts required a stern conversion, and included a low aspect/beam intercept (Intercept No. 2), three medium aspect/front-quarter intercepts (Intercepts 3, 4, and 5), and three high aspect/head-on intercepts (Intercepts 6, 7, and 8). The degree of difficulty increases as the aspect angle increases, with head-on intercepts being the most difficult. Mean scores on the head-on intercepts (Intercepts 6, 7, and 8) were selected as the test measure.

Performance was measured against a model of an idealized intercept. The data gathered by the computer included 30 measures of conformance to parameters of the idealized intercept. Scores assigned for each measure were summed to provide a single score for each intercept.

The student could earn a maximum of 1000 points on each intercept. Penalties for such errors as gimballing the radar, breaking lock, negative overtake during the conversion, failure to uncage the missile prior to launch, and excessive time to complete the intercept were subtracted from the intercept scores. Negative scores were possible and were in fact recorded by several subjects.

Class Differences

Because the AZ ANG course was a new course with no prior history, some changes between classes were to be expected. In the interval between Classes 04 and 05, the AZ ANG changed the training from running baseline intercepts to running air defense intercepts. The baseline

intercept requires going to a collision course immediately upon acquiring the target on all intercepts. The air defense intercept requires going for turning room immediately during front-quarter and head-on intercepts. This required a change in scoring. The points awarded for establishing and maintaining collision during baseline front-quarter and head-on intercepts (100 points) were transferred to the subtask of establishing and maintaining turning room (previously 200 points) during the air defense intercept, in order to retain the total number of points per intercept at 1000.

Between Classes 05 and 06, the Guard changed the interval between the AIT lessons. During Classes 04 and 05, the AIT lessons had been given on separate days, giving subjects time to assimilate the training. During Class 06, HR3 and HR-4 were presented on the same day.

To adjust for the changes in procedures between the three classes, a class variable was used in the data analysis. The class variable has the added benefit of adjusting for history.

Instructor Differences

Seventeen different IPs were used by the Guard for the one-on-one training and the conversion flights in Tucson. Five IPs were used for the AIT instruction at Williams AFB. The assignment of IPs to subjects for individual lessons was a function of the availability of the instructor and subject and hence was somewhat random, except for subjects in Group 1. Subjects in Group 1 might have been assigned any one of the IPs for the symbology/switchology lesson (HR-2), but had only one of two IPs for the target detection lesson (HR-3), and all had the same instructor for the intercept lesson (HR-4). Based on a preliminary analysis and on the fact that one instructor had been used for most of the Group 1 students in the target detection lesson and all of them in the intercept lesson, the instructor assignment for the symbology/switchology lesson was used as a blocking variable in the analysis of the data.

Hypotheses

The hypotheses being tested in the research were that, a) the performance of subjects given the initial AIT training would not differ significantly from that of subjects given the lecture and tape training, b) the performance of subjects given the added AIT training at Williams AFB would not differ significantly from that of subjects given no additional training, and c) the performance of subjects given the additional training in the flyable mode would not differ from the performance of subjects given the additional training in the nonflyable mode.

Data Analysis

The data were analyzed using a randomized block design with instructor assignment on HR-2 defining the blocks. Orthogonal contrasts were used to test the hypotheses. Because of the small n's and the high variability expected in the data, we selected a level of significance of .10 for all significance tests.

RESULTS

The mean scores obtained are presented in Table 1. Individual scores and group means are presented in Figure 2. The overall mean was 497. The median score for all subjects was 503. The median scores for the subjects in the individual groups were 306, 455, 542, and 610, respectively.

Table 1
Mean Intercept Performance Scores by Groups

Class	Group 1 Lect/Tape	Group 2 AIT	Group 3 AIT+(nf)	Group 4 AIT+(f)
No. 04	269	552	516	586
No. 05	193	504	690	608
No. 06	648	418	552	497
Overall Means	370	492	585	563

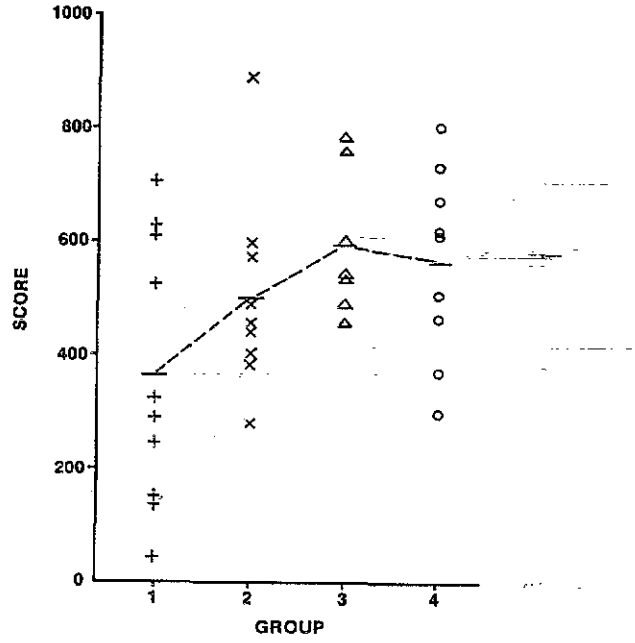

FIG. 2: INDIVIDUAL AND MEAN SCORES BY GROUP

There was no main effect for the instructor variable, so the instructor variance was pooled with the error variance. There was then a significant effect at the .031 level due to group membership, df=3,15, F=3.87. There was no class effect, but there was a significant interaction at the .022 level between group and class, df=6,15, F=3.52.

The difference in performance between the subjects in Group 1 and those in Group 2 was significant at the .090 level, df=1,15, F=3.28. The difference in performance between the subjects in Groups 1 and 2 and those in Groups 3 and 4 was significant at the .016 level, df=1,15, F=7.34. The performance difference between the subjects in Groups 3 and 4 was not significant.

The interaction was based principally upon a difference in the performance between Group 1 and Group 2 students in Classes 04 and 05 and those in Class 06, significant at the .090 level, df=1,15, F=13.27. There is a significant reversal of the relationship between the means, as is indicated in Figure 3. The performance of the Group 1 subjects in Class 06 was well above the performance of any other members of Group 1, and was above the 70th percentile in the overall data. By way of contrast, the performance of the Group 2 members of Class 06 was below the mean for the previous two classes, and at about the 33rd percentile in the overall data.

Contribution of Breaking Lock and Gimballing

The principal contributor to the variation in individual scores was the effect of breaking lock or gimballing the radar after target acquisition. The penalty for breaking lock without reacquiring within 20 seconds or for gimballing the radar was severe (-400 points), as it would be in the real world, and accounted for the lowest individual scores on every intercept. Scores on individual intercepts for subjects who broke lock or gimballed the radar ranged from -525 (for a student who gimballed, reacquired the target, then broke lock) to 315 (for a subject who broke lock early, then reacquired). The performance range for subjects who avoided breaking lock or gimballing the radar was from a low of 350 to a high of 945. The difference in frequency of breaking lock or gimballing was significant, df=3, Chi-square = 10.60, $p < .05$. Subjects in Group 1 gimballed the radar significantly more often than did subjects in Group 2; 12 gimbals versus 5, df=1, Chi-square = 3.23, $p < .10$. Subjects in Groups 1 and 2 gimballed the radar more frequently than subjects in Groups 3 and 4; 17 gimbals vs 5, df=1, Chi-square = 6.02, $p < .05$. The frequency of gimbals for each student is indicated in Table 2.

Table 2.
Gimbal Frequency for Each Student by Group

		% gimbals
Group 1:	1, 2, 0, 3, 2, 2, 2, 0, 0, 0	40.0
Group 2:	0, 0, 0, 0, 1, 2, 1, 1, 0	18.5
Group 3:	0, 0, 0, 0, 0, 1, 0	4.8
Group 4:	0, 0, 1, 0, 1, 1, 0, 0, 1	14.8

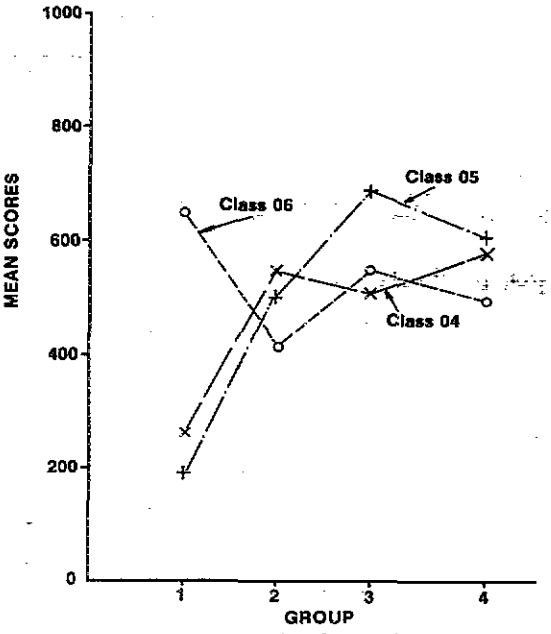

FIG 3: GROUP INTERACTIONS

DISCUSSION

As Figure 2 indicates, there was considerable variability in the scores. In general, the lower scores were the result of gimballing the radar. Subjects whose scores were above the median (503) did not gimbal the radar on any of the three test intercepts, while all 13 subjects whose scores were below 450 gimballed the radar at least once, and all six subjects with scores below 290 gimballed the radar two or more times. Gimballing the radar usually indicates that the subject was unable to interpret the symbols on the HUD/REO displays correctly. After target acquisition, the HUD/ REO displays give the subject all the information he needs to develop the intercept, provided he understands what he's seeing. Further, the onset of a situation that will lead to gimballing the radar is very apparent in the displays and can be corrected by proper aircraft control. Since the entry level skills of the subjects included extensive experience running intercepts, albeit in a different aircraft, failure to avoid gimballing is a substantial indication of a lack of understanding of the intercept geometry indications of the HUD/REO displays. The fact that the subjects trained via lecture and tape gimballed the radar more often than those who had had AIT experience, clearly indicates that the AIT makes a positive contribution to that understanding.

The absence of difference between the subjects in Groups 3 and 4 is surprising. This result suggests that simply viewing the computer-generated intercepts was more effective than

actually 'flying' them. One facet of the question, however, is that the nonflyable (computer-controlled) intercepts conformed to the intercept philosophy used in the research, so that the experience of the nonflyable group paralleled and reinforced their experience at Tucson, where the intercepts were also conducted in nonflyable mode. The subjects required to fly the intercept had to generate the intercept while at the same time learning to fly the AIT, a new learning experience. Because of the interference of the new learning, and to the extent that their performance in the AIT deviated from the prescribed intercept, they would have been less well prepared to perform research intercepts.

The performance of subjects in Groups 3 and 4 was little better than that of the subjects in Group 2, and, in fact, the subjects in Group 4 gimballed the radar almost as frequently as did the subjects in Group 2. Comparing the results of the experiment to the comments of instructors, subjects, and observers alike, who were of the opinion that the hands-on experience as a predecessor to going in the OFT was extremely beneficial, and even more specifically that the flyable mode was a significant contributor to understanding the intercept, raises a question as to what factor is at work in the experiment. One possibility, the interference of the new learning, was discussed in the last paragraph, but it doesn't apply to the Group 3 students. Their added practice should have helped. A study to control for all the variables except the added practice seems very much needed.

Following the completion of the research intercepts, all subjects had additional training in both the flyable AIT and the OFT. The uniform comment of the contract instructors who administered these lessons was that the pilots were performing intercepts very well by the time they finished these lessons. Although there were clearly individual differences in performance during these exercises, there was no evidence of any difference in performance as a residual effect of the research treatments used in the experiment.

CONCLUSIONS

It is concluded that the intercept training of conversion pilots is significantly enhanced by the use of the AIT. Individuals taught using the AIT develop superior intercept skills and are better prepared to run effective intercepts in the OFT. It is also concluded that the flyable mode of AIT training is not significantly superior to the nonflyable mode, albeit the opinions of instructors, subjects, and observers differed from the results. Data to eliminate this conflict between results and opinion are needed.

Additional data should be gathered to either confirm or modify the indications of the current research. It is recommended that data be gathered to determine whether, in fact, giving added training in the AIT when subjects come to Williams before putting them in the OFT improves the student's preparation. It is also recommended that data be gathered from pilots with no prior intercept training, to determine whether the AIT will have an even greater impact on training for those pilots who have had no previous experience in interpreting radars and visualizing the geometry of intercepts. It will also be desirable to discover whether the flyable feature of the AIT makes a significant difference when training the less experienced pilot.

Research counts now a number of successful part-task training devices built around microprocessor technology. Although the individual devices differ as to the skills taught, all have contributed or are currently contributing significantly to aircrew training. The proven ability of the AIT to enhance the acquisition of a higher level aircrew skill portends an expanded future for devices of this type.

ABOUT THE AUTHORS

Dr. Lahey is a Research Psychologist with the University of Dayton Research Institute, Flight Training Research Support Group, working at Williams AFB. He holds a doctorate in Educational Psychology, and has been doing training research for the Navy and for the Air Force over the past 18 years.

Dr. Hubbard is a Research Psychologist with the University of Dayton Research Institute, Flight Training Research Support Group, working at Williams AFB. He holds a doctorate in Experimental Psychology and the equivalent of a Masters in Applied Statistics. He has been doing training related research for the past nine years.

Dr. Edwards is a Research Psychologist with the Air Force Human Resources Laboratory group at Williams AFB. He holds a doctorate in Educational Psychology, and has been doing training research and analysis for the Air Force over the past 15 years.