DESCRIPTION AND INITIAL EVALUATION OF A COMPUTER-BASED INDIVIDUAL TRAINER FOR THE RADAR INTERCEPT OBSERVER

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INTRODUCTION

The Radar Intercept Officer (RIO) is a critical element in a complex man-machine relationship which emerges ultimately as a weapons system. The complexity of the basic delivery device, the aircraft, and the high speeds at which it usually operates create operational situations which tax the maximum performance capabilities of a single individual or pilot. Extended-range weapons, such as missiles, and high aircraft speeds render visual methods of target acquisition virtually useless, and have led to the development of sophisticated electronic devices for this purpose.

The pilot is the first element in this weapons control system, maintaining the precise operation of the aircraft. The RIO is the second integral element of control, analyzing data concerning target activity, and transmitting to the pilot action control commands based on these data.

The RIO is engaged in multiple tasks during an air intercept. He must (1) manipulate the electronic equipment in a manner that maximizes its capabilities as an information source, (2) gather and integrate electronic data with previously learned data and procedures, (3) decide upon actions that may be performed within the operational limits of the aircraft to meet weapons launch criteria, and (4) produce accurate verbal commands that constitute adequate control functions.

ANALYSIS OF THE RIO'S TASKS IN AIR INTERCEPTS

The Radar Intercept Officer (RIO) in the flight environment performs a complex mixture of cognitive and manual tasks under the extremes of psychological and physical stress.

The basic element of interception is the solution of a problem in relative motion, in itself a difficult problem to conceptualize and solve. The RIO gathers the data for the solution of this problem from (1) his own aircraft's instruments which display flight parameters, and (2) a radar display from which the relative position and movement of the opposing aircraft (bogey) may be derived by visual observation and interpretation. From

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This work was done under Contract No. N61339-71-C-0219, with the Human Factors Laboratory, Naval Training Equipment Center, Orlando, Florida.

this observed data, the RIO will derive estimates of the opposing aircraft's flight parameters. He may receive initial estimates of these from a ground or shipboard radar site where circumstances so permit. Ground radar data is usually provided during the early phase of training, until the RIO has developed a reasonably effective intercept capability.

Elements of the RIO's Intercept Tasks

The activities of the RIO during an intercept may be divided into four major task components.

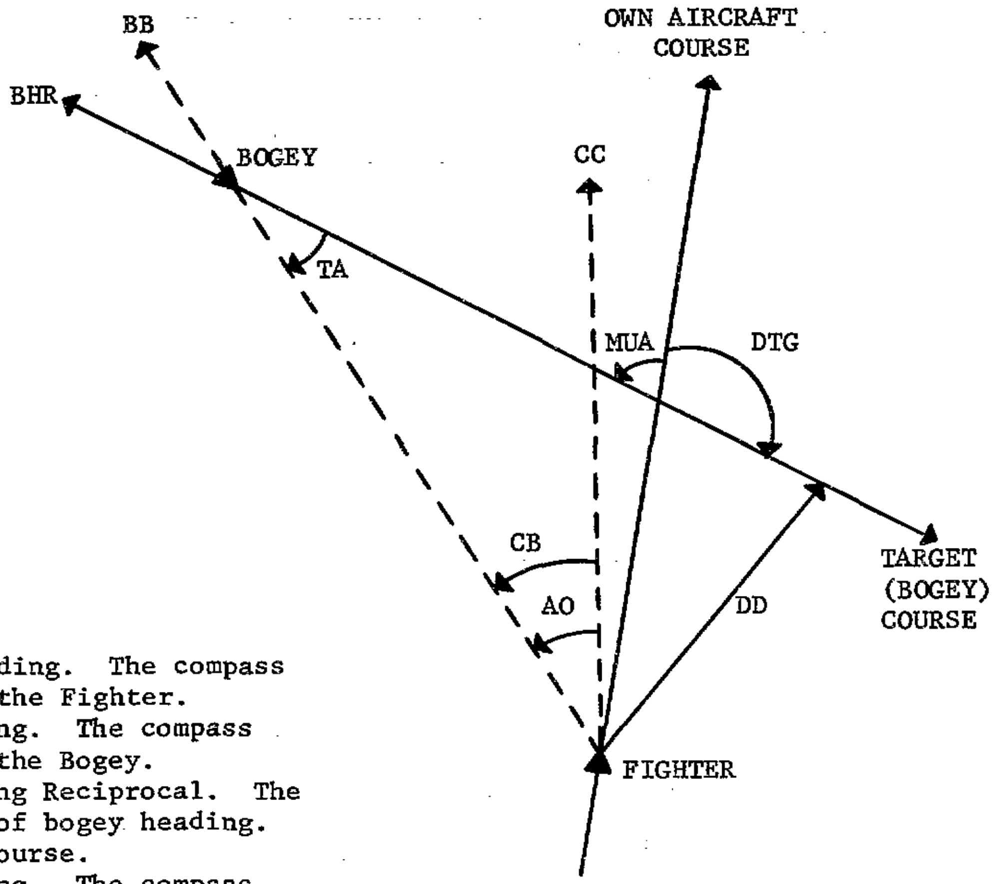
Radar Operation. The first is the operation of the radar system to monitor (or track) the bogey's movements. The radar system must be operated in a manner that will maximize its capabilities for target acquisition. The operational capabilities of the radar system will vary widely with changes in the external environment, particularly weather. Since the electronic emission characteristics of the radars are fixed, the RIO must vary the display of gain and contrast to maximize his own target detection and tracking potential. Additionally, he must manually manipulate the antenna elevation position during search until such time as the opposing aircraft is within the automatic tracking envelope of the radar system. Display control, antenna control, and mode control must be performed with the other elements of the intercept process.

Information Gathering via Display Interpretation. The second major task component is the derivation of target data from observation of the relatively complex display format of the radar system. Radar displays vary with the type aircraft in which the RIO performs his mission. Display attributes analyzed here are those of the radar training system (AN/APQ 94-T1) utilized in RIO basic training at NAS Glynco, Georgia.

The particulars of the AN/APQ are published in NavWeps 01-60GBA-2-6.1 (declassified 5 January 1972) and will not be discussed in detail. There are some aspects of the display, however, which appear pertinent to the RIO's scope-interpretation problem.

The size of the display is four inches high by two inches wide. The vertical of the display corresponds to range and may represent a maximum of 20, 40, or 60 miles as selected by the RIO. The width of the display represents antenna azimuth and represents a 90° sector of space 45° left and right of the aircraft heading. The position of the target return on the display determines its range from the fighter and its azimuth, termed "Angle Off." The large scale factor limits the RIO's discrimination of both range and azimuth. Bearing discrimination is probably degraded by the lack of reference marks along the azimuth dimension.

Added to the discrimination problem is the presence of supplementary display elements which the RIO must control manually and observe visually. These include the acquisition symbol, artificial horizon bar, antenna tilt symbol, and five function lights that ring the display. In the track mode, the ROC circle, missile climb capability symbol, and missile maximum range symbol are added to the display.



FH - Fighter Heading. The compass heading of the Fighter.

BH - Bogey Heading. The compass heading of the Bogey.

BHR - Bogey Heading Reciprocal. The reciprocal of bogey heading.

CC - Collision Course.

BB - Bogey Bearing. The compass bearing at which the Fighter would visually observe the Bogey.

CB - Collision Bearing. The constant compass bearing at which the Bogey will be seen when on Collision Course.

AO - Angle Off. The angle relative left or right of Fighter's longitudinal axis where the Bogey would be visually seen.

TA - Target Aspect. The angle relative left or right of target's longitudinal axis where the Bogey would visually observe the Fighter.

MUA - Make-Up Angle. The angle formed by BHR and FH.

DTG - Degrees (of heading change) to go to target course.

DD - Displacement Distance. The perpendicular distance from the Fighter to the Bogey track.

Figure 1. AIR INTERCEPT GEOMETRY

Information Analysis, Integration, and Decision Making. Initially, with the entry into an active intercept, the RIO must perform a series of specific arithmetic computations and transformations vital to the establishment of his spatial relationship to the opposing aircraft. Through these mathematical steps, values are established for the elements of the intercept triangle. The intercept triangle is a hypothetical figure which one might draw as representative of the spatial relationships that presently exist, and will exist over some time period, between the interceptor and opposing aircraft. The intercept triangle provides the mathematical and conceptual basis for the intercept as a process. It is the geometric figure formed by the fighter's path of flight, the bogey's path of flight, and a hypothetical line connecting the fighter and bogey at any instant of time. The angular and linear (distance) relationships thus established form a basis for the management of relative motion, and for predicting the future relative positions of the two aircraft. An example of the intercept triangle is depicted in Figure 1. Any change in the flight parameters of either aircraft will change their spatial relationship, and thus the quantities which determine the triangle's form.

Two values within the intercept triangle, the angular size of TA, and the linear value of range (RG) (the distance between the fighter and opposing aircraft) literally "control" the actions of the RIO up to a certain point in the intercept. This point varies with the type weapon being utilized by the fighter. In reality, there is some degree of variability in this limiting relative position, determined by certain aircraft characteristics such as turn radius and turn rate. There is, therefore, a certain volume of space located relative to the enemy aircraft through which the fighter should pass to perform a successful intercept. If he fails to pass through this intercept aperture, it may still be possible to complete an intercept, but at the cost of excessive maneuvering, high "g" turns, and greater fuel usage, to name only some of the requirements. Under these latter conditions the probability of a successful intercept is materially reduced.

Mathematical Computations. Under the best of conditions, the RIO will commence an intercept with knowledge of the enemy aircraft's base course and speed, as well as his range and compass bearing from the fighter. With these elements known, and his own course and speed, the RIO may "solve" or compute the values of the intercept triangle needed to close on the enemy.

A series of computational algorithms are utilized in the resolution of this problem. These algorithms must be learned and recalled as necessary. The computations require little mathematics beyond simple arithmetic. However, certain angular values are labeled either left or right with reference to either the fighter or enemy aircraft's compass heading. The determination of Left-Right labels for Target Aspect, Angle Off, and Make-up Angle becomes non-trivial for the neophyte RIO.

High aircraft speeds bring the two aircraft into close proximity within a maximum of 2 to 3 minutes, and usually less. The RIO must learn to calculate rapidly, and with little error. An error, once made, seldom can be fully corrected within the time remaining to intercept. Rapid closure, numerous calculations, and the need to continually manipulate the radar. essentially prohibit recording calculated values. The RIO must hold the results in his memory as he progresses through the list of operations.

Integration and Decision Making. It must be presumed that the RIO compares his observations with some internalized model of the intercept process. This internalized model generates expectancy data based upon initial orientation and past maneuvers. The internal process model predicts such values as drift and drift rate of radar returns, range and changes in range, and the change in bearing or bearing limits in time. When a specific change of a flight parameter does not produce the predicted relative movement, the RIO must initiate a corrective change in flight parameters. Determination of intercept progress is derived from the "B" scope presentation once the bogey has been acquired on radar. Changes in flight parameters to produce a specific relative motion are subject to errors in display interpretation and in computation. The necessity to shift attention to radar manipulation may produce time-related errors. The RIO may fail to calculate correct flight parameters because his attention is focused on the radar.

Control Commands to the Pilot. The fourth element in the RIO's flight task is the verbalization of his decisions in the form of commands to the pilot to modify the aircraft flight parameters. Verbalization of decisions concerning the intercept demands a greater amount of RIO attention than would appear necessary, particularly for the RIO student. The verbalization of commands acts as an intrusion into other processes demanded by other task elements.

THE INSTRUCTIONAL STRATEGY

The opportunity to develop individual job skills through intensive practice in a permissive environment can be provided by computer-controlled individual trainers. These devices can be designed so that instructor monitoring is not continuously required. They can be sufficiently responsive to individual differences to eliminate time wasted by traditional "lock-step" training methods.

As has been outlined above, the RIO's role involves a number of different kinds of tasks. The RIO often has a high information-processing load to deal with in a real-time, essentially hostile, and therefore stressful, environment. It is essential that he develops fluency in performing these tasks so that he can successfully process information at the rates demanded by real-time tactical operations. It is well known that intensive practice can enable the performance of tasks without constant attention, freeing the focus of attention for higher-order considerations. Intensive practice under proper conditions also results in a performer with more confidence in himself and more resistance to perturbation by stress (Kay, 1970). The following are major features of the instructional strategy:

1. Enough features of the job-environment are simulated to provide a realistic context.

2. Basic information-processing tasks (computing values in the intercept triangle) are assigned a special, "static mode" in which bogey and fighter speeds are 0, so that the student can build up fluency to the point that he can keep up with real-time demands later, when bogey and fighter are travelling at speeds up to 500 knots.

3. Immediate knowledge of results is provided for all intercept-triangle values and for the outcome of the intercept problem. Latencies (in seconds) are provided for the mental computations.

4. Displays of the intercept geometry are provided, both as computer-controlled (automatically shown after the student makes an error) and as student-controlled (depress function key) features. In the static mode, a static intercept triangle is displayed. In the dynamic mode (bogey and fighter moving), the true motion of the two is displayed by a triangle that changes shape as the intercept develops. The student can compare the true motion seen in this display with the relative motion seen on the simulated B-scan that also is displayed. The intercept geometry at the time of firing also is displayed, showing jet heat-cone and missile acquisition-cone, and a probability-of-hit figure.

5. An updated display of all the intercept triangle values is automatically provided in a "toteboard" if a student makes a computational error during the dynamic phase of practice. The student also can see this display by hitting a function key.

6. The student can temporarily stop the real-time problem by hitting a function key, if he feels he is getting behind the problem.

7. Four problem categories, each with 16 intercept problems, representing different initial positions, headings, ranges, and values of Angle Off are presented in four sectors (quadrants) and at eight different bogey and fighter speeds. Speeds increase by 40-knot increments, from lowest to highest. These combinations provide 512 practice problems. Heading and bearing values are changed as the student progresses from static to low to high speed levels.

8. Trials-to-criterion logic automatically moves each student to the next speed level as soon as he solves four problems in succession with no errors, no use of on-demand functions, and all probabilities of hit at or above .80.

9. If a student achieves less than a P-hit of .80, the computer automatically puts him into a "free-fly" mode and that same problem is repeated in this mode. In the free-fly mode, the displays of the intercept triangle, of the B-scan, and of the updated triangle values in the toteboard, are continuously on the CRT. The student "flies" the fighter by issuing turn commands via the keyboard. In this way, students can experiment to find the best interception path to fly, and can relate numerical values of variables to the true motion of the intercept triangle and to the relative motion on the B-scan.

THE CAI SYSTEM

The hardware part of the trainer is a programmable graphics terminal, or "smart" terminal,generally used in conjunction with a larger computer, either as a remote terminal in a time-sharing system or hard-wired into other types of systems. However, this terminal includes features that make it well suited for use as part of a small, stand-alone CAI system in military training environments where geographic and size-of-school constraints make large, centralized CAI systems impossible or uneconomical. The terminal is compact, occupying less space than a small desk. The graphics CRT, two minicomputers, up to 16K of core, and a variety of special processing, graphics, and IO accessories are contained in this space. The terminal contains two programmable minicomputers, one general purpose, and one for display processing. The cycle time of 1.8 usecs is fast enough to permit generation of relatively complex, animated graphics displays within the normal 40 cps refresh rate. The hardware is organized for micro-programming, which provides for an extensive instruction repertoire for standard data-processing. The terminal keyboard is completely programmable. The keys are treated essentially as peripheral input devices. Depressing a key sets a programmed flag and enters the octal code identifying that key in a register. What happens after that is entirely up to the programmer.

Programs and data can be loaded into core memory relatively rapidly from audio-tape casettes. Since the programs define the "course" that is to be implemented by the trainer, the hardware described above can be used for as many different "courses" as can be programmed.

Together, these features make an attractive potential for an individual-skills trainer for tasks that must be performed in real-time and that involve graphics displays in the operating environment or that could be learned more quickly through the mediation of special graphics displays.

THE COMPUTER PROGRAMS

In this type of trainer, the computer program creates the instructional environment, implements the instructional strategy, and records and analyzes the data. In a very real sense, the software <u>is</u> the trainer. In this case, the program consists of approximately 7500 instructions and intercept problem specifications written in assembly code. Some appreciation of this program can be gained from considering the following major operations it implements.

1. It accepts and responds to the student's entries via the keyboard. Each function key is implemented by a subroutine in the program. In a sense, depressing a key is equivalent to a subroutine call.

2. It provides three instructional modes: static, dynamic, and free-fly. In the static mode, students practice performing the mental arithmetic necessary to compute values of intercept triangle variables, given initial positions and headings of fighter and bogey. This mode is called static because the fighter and bogey fly at zero speed. A "toteboard" display is continuously present in the static mode. This display lists initial headings of

fighter and bogey, bogey range and bearing, and the intercept triangle variable names in following rows. When the student computes a value for a variable, it appears in the toteboard opposite the name. If the student's value is incorrect, after 3 seconds it disappears. If the value is correct, it remains in the space adjacent to the variable name, and an arrow at the right end of the row moves down to the next row. The student can try to compute the correct answer as often as he wishes, but latency to correct response is recorded, and he knows an objective of the practice is to reduce latency. As a last resort, the student can depress the answer key, which causes the correct answer to be displayed adjacent to the variable name.

On the first error the student makes, the intercept triangle for that particular problem is automatically displayed on the screen above the toteboard, so that the student can see the geometry of the situation.

In the dynamic mode, the fighter and bogey are flying at any of eight speeds. The student must compute values for the intercept triangle as he did in the static mode, but while he is doing this, the problem is progressing. The longer the total latency, the further he gets behind the current situation. However, values in the toteboard are based on initial conditions until the student enters the correct collision course. At that point, the fighter turns to collision course and toteboard values are recomputed on the basis of the new heading. The toteboard values disappear after the student enters a value for Angles Off. Updated values from then on are available to the student if he depresses a function key. Similarly, the intercept triangle is also available by depression of a function key. The primary display in the dynamic mode is the simulated B-scan, including target acquisition, turn indicator, rate-of-closure circle, and full and sector scan.

The student's task, after he solves for intercept triangle values, is to learn to use the B-scan to fly the fighter through a Sidewinder intercept. Three major turns are usually involved: to collision course, for displacement distance, and the firing turn. Minor turns to correct for drift on the B-scope also may be necessary. The intercept is ended by the student depressing the "FIRE" key. This causes the geometry at the moment of firing, including a hit probability, to be displayed.

If the student makes an error while computing values for the intercept triangle, a moving version of the triangle geometry is displayed on the screen above the B-scan, so that the student can watch the problem develop in "true" motion and can compare this to the relative motion seen on the B-scan.

The "free-fly" mode is entered from the dynamic mode. If the P-hit for a problem is less than .80, the student is automatically shifted into the free-fly mode, where he repeats the problem. In this mode, all the updated displays are continuously available; the toteboard, the B-scan, and the dynamic triangle. The student can use information from these numerical and geometrical displays while flying the fighter through the intercept. He can repeat a problem as often as he wishes until he feels he has mastered it.

3. The program simulates interceptions by computing the positions and headings of fighter and bogey every 1/10 second and every time the student changes fighter heading. The computational subroutines compute the values of

all intercept triangle variables, using trigonometric functions, and a vertical reference (on the screen) that takes on any of four values in degrees, 360 (or 000), 90, 180, or 270, representing the four quadrants in which an intercept problem is displayed. The problems are driven by the speeds at which the aircraft move. The turns of the fighter are driven by turn rates for a trainer aircraft using any one of four "doctrine" turns. The outputs of the computational subroutines are used in a variety of other subroutines: to correct students' answers, to display correct values in the toteboard, to update the B-scan and intercept triangle displays, and to provide the basis for computing hit probabilities.

4. The program generates all the displays described above: the alphanumeric toteboard, the static and dynamic triangles, the B-scan, and the fire geometry. The subroutines to do this are written in display instructions and are implemented by the display processor mini-computer. The general-purpose mini-computer can be said to be the dominant of the two computers, since it not only watches the clock and turns the display processor on, it also makes up the "display list," consisting of a series of jump (to display subroutines) commands, and stores this list in core. The display processor then executes this list, one jump (one subroutine) at a time, by reading each instruction from core. (The display processor cannot write on core.) The display processor steals one fetch cycle from the general-purpose mini each time it accesses core. When it has finished the entire display list, it turns itself off and waits for the other mini to turn it on again at the start of the next 1/40th of a second.

5. The program records student response histories, implements trials-to-criterion logic, provides knowledge of results to the student, and transforms response histories into permanent records. The trials-to-criterion logic provides for moving the student from the static phase to the dynamic phase and to successively higher speed levels in the dynamic phase each time the student achieves a criterion of four successive problems with no errors and within acceptable time limits. Knowledge of results are provided as described above in discussing the modes. Recording the response histories on permanent records could be done in any of a number of ways. Because the initial data were collected on a military base geographically remote from the nearest time-sharing access point, telephone lines out of the base could not be tied up, and the terminal had only 8K memory, student data were punched on paper tape, using a teletype tape-punch on-line with the terminal. Student responses, scores, and a time and range base were written on a short buffer memory. This buffer was read out and the contents were punched on tape in real time, i.e., as the data were generated by the student. The buffer served to protect against data loss due to the slow punch speed (110 baud) of the teletype. Student responding might otherwise get ahead of tape punching. This procedure proved to be a satisfactory expedient for that environment, since a silencing case could be fitted over the teletype.

The RIO trainer can generate a phenomenal amount of data. Consider that each student practices with the trainer for 10 hours. In that time he may work through several hundred problems. Each problem can yield 34 different units of data, and many of these units may occur several times during the course of a problem. The result can be roughly 5,000 to 10,000 data items per student. Clearly, these data must be analyzed by a computer.

THE DESIGN FOR THE FIELD TRIAL

The intercept trainer was installed in the RIO school at Glynco, Georgia for preliminary evaluation of its validity, reliability, and acceptability in that training environment. Two types of validity were of immediate interest: instructional strategy validity for improving student performance in the flight phase of air-to-air intercept training, and content validity in relation to the curriculum and training methods in use at the school. After inspecting the trainer, the school staff suggested several minor changes in the displays and procedures. These were made as running changes over approximately the first month the trainer was in operation at Glynco. The data for the group (four students) from the first class that used the trainer were therefore not included in the data analysis.

Establishing that the individual trainer does or does not improve student performance in the subsequent flight phase of the RIO course is a matter requiring a series of studies and relatively rigorous control over situational variables. For the preliminary evaluation, a two-random groups post-test only design was planned, using groups randomly constituted from each RIO class in turn, and using an in-flight instructor checklist as the measure of dependent variables. It would have been more desirable to have recorded student data in-flight essentially identical to that recorded automatically on the ground by the BTL trainer. However, facilities for doing this would have required resources beyond the scope of the project.

DATA ANALYSES

By far the largest volume of data was automatically recorded, by procedures described earlier. This is a significant new capability computers bring to the training environment. Response-by-response histories can be recorded, providing a "micro-view" of student progress.

Analysis of Automatically Recorded Student Response Histories

The summary data consist of means and standard deviations listed for the static mode (speed of bogey and fighter = 0) and for the eight speed levels in the dynamic mode. Since the students progressed from the static mode through the dynamic mode speed levels (220 knots to 500 knots), the row trends in the tables reporting student response data reveal changes attributable to practice, as driven by higher and higher speeds. For example, means and standard deviations for latencies decreased.

Initial Target Aspects

Variables that defined differences among intercept problems were quadrant of the compass in which they occurred, initial positions and headings of bogey and fighter, initial range, and speed. Initial positions also defined target aspect, the angle off the bogey's nose formed by the intersection of the fighter heading with the bogey heading. Target aspect influences intercept tactics. For example, at low target aspects, the fighter may have to turn out to achieve adequate displacement distance before turning in for a Sidewinder attack. Therefore, the means and standard deviations were computed for target aspects of problems in each of the four categories of problems that were the basis for problem sequencing and for the trials-to-criterion logic. These data, given below in Table 1, indicate that this variable was reasonably well controlled within each category. Data are summarized in terms of each of the four problem categories in all of the following tables.

Table 1. Initial Target Aspects

	STATIC PHASE	DYNAMIC LEVELS: SPEED 220	260	300	340	380	420	460	500	ROWS
MEAN	0.	2.7	2.8	2.9	3.1	3.1	3.4	3.1	3.1	3.0
STD DEV	0.	2.0	1.8	1.9	2.0	2.0	2.2	2.3	2.2	2.1
MEAN	0.	10.1	10.2	10.3	10.0	10.1	10.4	9.9	10.1	10.1
STD DEV	0.	1.8	1.8	1.8	1.7	1.7	1.8	1.7	1.7	1.7
MEAN	0.	17.6	17.6	17.6	17.6	17.5	18.3	17.7	17.9	17.8
STD DEV	0.	3.3	3.1	3.1	2.9	3.2	3.3	3.1	3.1	3.1
MEAN	0.	31.8	32.2	31.3	32.1	32.5	30.7	33.0	31.5	31.7
STD DEV	0.	6.9	6.1	5.7	5.9	6.4	4.7	7.0	5.9	6.2
COLS	0.	15.8	15.8	16.4	15.7	16.7	15.6	15.3	15.6	15.8
	0.	11.4	11.2	11.2	11.1	11.5	10.7	11.5	10.9	11.1

<u>Problems Attempted and Completed in Static, Dynamic, and Free-Fly Modes</u>

Both trials-to-criterion and fixed-learning-time logic were used in this study. Students could progress to the next speed level by solving four successive problems with no errors and a probability-of-hit (in the dynamic mode) ≥ .80. However, the school assigned a block of ten hours for each student to practice on the BTL trainer. Thus, if a student transitioned to the highest speed level, 500 knots, before he used his ten hours, he remained at that level until he finished ten hours of practice.

The subsequent detailed analyses were performed on Numbers of Problems Attempted, since fine-grained information, e.g., latencies for triangle values and turns (number, degrees, type), was contained in these problems even though the student may have made a poor score or may have committed some errors.

In the static mode, a problem was classified as attempted if the student finished all six triangle variables, even though he made one or more errors or took more than 120 seconds; in the dynamic mode, a problem was classified as attempted if the student completed at least one turn after Collision Course, or if he completed the intercept but his P-hit score was less than .80.

In some of the tables, some values are so close to zero that rounding operations produced minor discrepancies between values of means and standard deviations; e.g., a mean of 0.0 and a standard deviation of 0.1 or 0.2.

Probability of Hit Scores

The probability of hit score at the end of an intercept problem indicated to the student how well he had placed the fighter for firing. This score is a terminal index, and as such probably is a better measure of the student's skill in turning to attack than of his skill in earlier maneuvers. Nevertheless, he would necessarily have to be successful in placing the fighter in a "window" located off the near side of the bogey to make a turn to attack feasible. The criteria for transitioning to a higher speed level included the requirement that P-hit ≥ .80.

These "final scores" for the problems flown in the dynamic mode are summarized (P-hit x 100) in Table 2. The students evidently were able to increase the P-hit score up to the 340 kt speed level. Thereafter, the mean P-hit across all problem categories (bottom row) declined slightly. The 500 kt speed, at the initial ranges used, evidently gave the students considerable difficulty in the 8^{o} to 13^{o} target aspect problem category (second row of table). These scores increased, from .804 at 220 knots, to .943 at 340 knots, thereafter they decreased at the higher speed levels to .879 at 500 knots.

Table 2. Hit Probability (x 100) N = 29

	STATIC PHASE	DYNAMIC LEVELS: SPEED 220	260	300	340	380	420	460	500	ROWS
MEAN	0.	77.6	78.6	88.5	91.5	93.8	89.7	93.0	90.8	87.1
STD DEV	0.	39.3	39.3	30.6	25.6	21.0	30.1	24.1	27.4	31.7
MEAN	0.	78.7	91.9	87.8	97.5	98.3	90.2	83.6	81.5	85.1
STD DEV	0.	38.4	24.9	31.0	14.0	5.3	27.0	35.7	37.6	33.7
MEAN	0.	84.7	95.4	95.0	96.0	94.4	89.3	89.8	88.8	90.1
STD DEV	0.	33.6	18.5	19.8	18.3	22.1	27.8	28.4	29.5	27.7
MEAN	0.	80.0	86.3	90.1	92.7	89.3	96.3	89.2	89.5	87.8
STD DEV	0.	35.6	31.9	27.7	24.5	28.6	14.0	30.2	27.6	29.6
COLS	0.	80.4	88.4	90.7	94.3	93.8	91.3	89.3	87.9	87.7
	0.	36.8	29.8	27.1	21.3	21.5	25.7	29.3	30.6	30.6

Number of Turns

Students were able, as a consequence of their practice with this trainer, to decrease the number of turns they did during an intercept problem, as shown in Table 3. The low target aspect problems (row 1 of the table) required a slightly different tactic than higher target aspect problems. This is reflected in a slightly greater number of turns during low target aspect problems.

Table 3. Number of Turns

	STATIC PHASE	DYNAMIC LEVELS: 220	260	300	340	380	SPEED 420	460	500	ROWS
MEAN	0.	5.3	4.5	4.7	3.9	3.7	3.9	4.0	3.7	4.3
STD DEV	0.	2.7	2.0	2.2	1.3	1.4	1.4	1.4	1.3	1.9
MEAN	0.	4.7	4.2	3.5	3.9	3.7	3.8	3.6	3.4	3.9
STD DEV	0.	2.6	1.9	1.1	1.7	1.7	1.1	1.3	1.2	1.8
MEAN	0.	4.1	3.5	3.7	3.7	3.6	3.4	3.3	3.1	3.5
STD DEV	0.	1.8	1.4	1.9	1.6	1.1	1.2	1.1	1.1	1.5
MEAN	0.	4.7	3.7	3.6	3.4	3.6	3.3	3.2	3.3	3.7
STD DEV	0.	2.5	1.5	1.4	1.0	1.3	1.1	1.1	1.3	1.7
COLS	0.	4.7	4.0	3.9	3.7	3.6	3.6	3.5	3.4	3.8
	0.	2.4	1.7	1.8	1.4	1.4	1.2	1.2	1.2	1.8

Response Latencies

These data were recorded for each of the intercept triangle variables, and for major segments of an intercept problem. Inasmuch as the RIO students must learn to perform in real time in a rapidly developing situation, it is essential that they develop fluency in performing the mental arithmetic required to solve for the different triangle values, to minimize the extent to which they get behind the current status of the problem.

The latency data summarized here demonstrate that, overall, students did improve in fluency. This is shown in Table 4, in which latency values for the first (either static phase or first dynamic speed level (220 kt)) and last (500 kt) blocks of trials are listed. Mean latencies on the last trials were two to three times smaller than on the initial block of trials. There are no negative differences between pairs of means. A test of significance, using the Wilcoxon matched-pairs signed-ranks test, indicates the two distributions are significantly different, $P < .005$ for a one-tailed test.

Table 4. Latencies (in seconds) from First and Last Block of Trials
N = 29

LATENCY VARIABLE		FIRST BLOCK	LAST BLOCK	FIRST / LAST
To Complete Toteboard	M	67.9	25.8	2.6
	SD	46.4	10.0	4.6
To Collision Course (CC) Input	M	35.7	13.3	2.7
	SD	55.9	5.7	9.8
CC To Fire	M	238.1	101.7	2.3
	SD	83.5	25.0	3.3
Per Triangle Variable	M	11.5	4.8	2.4
	SD	12.4	3.2	3.9
Bogey Heading Reciprocal	M	8.3	3.8	2.2
	SD	8.0	2.2	3.6
Target Aspect	M	12.6	4.1	3.1
	SD	16.5	2.5	6.6
Collision Course	M	14.8	5.4	2.7
	SD	19.4	3.4	5.7
Make-Up Angle	M	13.9	4.8	2.9
	SD	15.7	3.3	4.8
Degrees-To-Go	M	6.9	3.1	2.2
	SD	8.2	2.3	3.6
Angle Off	M	11.4	4.6	2.4
	SD	12.7	3.2	3.9
		Overall Means	First / Last : M	2.5
			SD	5.0

ANALYSIS OF MANUALLY COLLECTED DATA

Analysis of checklist data indicated a slight but not statistically difference in favor of the experimental group (N = 23) in terms of in-flight performance. However, these data were not considered to be reliable or sensitive enough to be acceptable.

A consumer-acceptance questionnaire administered to the students (N = 26) revealed strong positive attitudes toward the trainer and its features.

SUMMARY AND CONCLUSIONS

An individual-skills trainer for the Radar Intercept Observer was designed around a "smart" terminal and was field tested at the RIO school in Glynco, Georgia. Data were presented to show that 10 hours of practice on the trainer improved fluency in performing basic tasks in air intercepts, latencies in performing mental arithmetic were dramatically reduced, probability of hit scores increased, and number of turns during an intercept decreased.

It is concluded that this is a viable approach to individual-skills training for use in conjunction with other learning experiences in the classroom. The scope of basic job skills covered by a trainer of this type depends primarily on the ingenuity used in writing programs for it. As the electronics technology develops the means for putting more powerful hardware into increasingly smaller packages, the "smart" terminal as the basis for computer-aided instruction in job environments, e.g., for shipboard training, will become even more attractive.

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