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Technical Report 948

The Effects of Easy-To-Difficult, Difficult-Only, and Mixed-Difficulty Practice on Performance of Simulated Gunnery Tasks

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The purpose of this report is to compare the effects of practicing easy-to-difficult, difficult-only, and randomly ordered, mixed-difficulty training exercises. The experimental task required tracking and shooting moving targets with TOPGUN, which is a tank-gunnery training device. Each of three groups of 20 undergraduates practiced three blocks of 36 exercises under one of three conditions: (1) easy-to-difficult progression of exercises, (2) all difficult exercises, or (3) randomly ordered, mixed-difficulty exercises. All groups were tested on 36 randomly ordered, mixed-difficulty exercises immediately after training. Dependent variables were target hits, aiming error, and time to fire. Results were that (1) learning occurred during practice; (2) mean differences among the groups' test scores were not statistically significant; (3) the group that practiced the easy-to-difficult progression and the group that practiced the randomly ordered, mixed-difficulty exercises hit significantly greater percentages of easy targets during testing than did the group that practiced only difficult exercises; and (4) the group that practiced the easy-to-difficult progression hit significantly greater percentages of difficult targets

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Training Simulation

FOREWORD

The U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) is committed to improving soldier performance by increasing the instructional efficiency of training devices and their built-in instructional subsystems. Because computer-based simulators are being used increasingly for military training, research that leads to improved efficiency of simulator-based training will necessarily yield increased savings.

ARI, in coordination with the Project Manager for Training Devices (PM TRADE) and the University of Central Florida's Institute for Simulation and Training, has begun a research program to examine alternatives to conventional simulator-based training. The research reported here is part of that program; it compares the effects of three methods for teaching psychomotor tasks: (1) easy-to-intermediate-to-difficult ("crawl-walk-run"), (2) difficult-only practice, and (3) mixed-difficulty practice.

The work described in this report is part of ARI Research Task 3104 and was performed under the October 1991 Memorandum of Understanding, "Advanced Technology for the Design of Training Devices." Plans and progress were briefed to PM TRADE's Chief Scientist, Ronald Hofer; former Product Manager (PM) for Close Combat Training Systems (CCTS), Colonel Richard L. Knox; and the Deputy PM for CCTS, Phil Sprinkle. Copies of this report have been delivered to PMs and other managers and engineers at PM TRADE.

The results of this research raise questions about conventional device-based training methods and will assist PM TRADE engineers, contractors, and others responsible for the design of instructional subsystems in gunnery and other training devices.

EDGAR M. JOHNSON
Technical Director

THE EFFECTS OF EASY-TO-DIFFICULT, DIFFICULT-ONLY, AND MIXED-DIFFICULTY PRACTICE ON PERFORMANCE OF SIMULATED GUNNERY TASKS

EXECUTIVE SUMMARY

Requirement:

This research compares the effects of practicing easy-to-difficult, difficult-only, and mixed-difficulty training exercises on students' scores on a test of mixed-difficulty, simulated gunnery tasks.

Procedure:

Each of three groups of 20 male undergraduates practiced three blocks of 36 trials under one of three conditions: (1) an easy-to-intermediate-to-difficult progression of targets; (2) all difficult targets; or (3) a randomly ordered mix of easy, intermediate, and difficult targets. The experimental task required tracking and shooting moving targets with TOPGUN, which is a tank-gunnery training device. All three groups were tested on 36 randomly ordered, easy, intermediate, and difficult targets immediately after training. Dependent variables were target hits, time to fire, azimuth error, and elevation error.

Findings:

Results indicate that (1) learning occurred during practice; (2) differences among the groups' scores on the test of mixed-difficulty exercises were not statistically significant for any of the dependent measures; (3) paid ROTC students achieved significantly greater hit percentages and significantly smaller aiming errors than did unpaid non-ROTC students, who received extra course credit for participation; (4) the group that practiced the easy-intermediate-difficult progression and the group that practiced randomly mixed targets achieved significantly greater hit percentages with easy targets during testing than did the group that practiced only difficult exercises; and (5) the group that practiced the easy-intermediate-difficult progression achieved significantly greater hit percentages with difficult targets during testing than did the group that practiced randomly mixed targets.

Use of Findings:

Several hypotheses and post facto explanations of the results were offered; their tenability can be established in light of additional research results. In the meantime, one implication for military training remains as Wolfle suggested in 1951: Practice should vary along the dimensions and range of values over which transfer conditions are expected to vary. Varied practice seems especially germane to training for situations for which we have less than complete knowledge about the characteristics of target arrays that will be encountered in combat. Training exercises should be juxtaposed in ways that not only promote proficiency on each exercise, but also promote learning of the discriminations necessary for proficiency in the face of novelty and variety. Exact strategies for optimizing efficiencies among acquisition, retention, transfer, and generalization, however, remain to be discovered.

THE EFFECTS OF EASY-TO-DIFFICULT, DIFFICULT-ONLY, AND MIXED-DIFFICULTY PRACTICE ON PERFORMANCE OF SIMULATED GUNNERY TASKS

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THE EFFECTS OF EASY-TO-DIFFICULT, DIFFICULT-ONLY, AND MIXED-DIFFICULTY PRACTICE ON PERFORMANCE OF SIMULATED GUNNERY TASKS

Introduction

Nearly all modern training devices incorporate instructional subsystems, which include software and instructions for use that prescribe an instructional procedure, a sequence of exercises, or both. The built-in instructional subsystems are more likely to be used by the instructor-operators responsible for training than are alternative procedures, for at least two reasons: (1) instructors' belief that the built-in systems offer instructional sequences that are sufficient for learning, and (2) the inefficiency of alternatives, whose use requires instructors' programming unique sequences of exercises, essentially creating a new instructional procedure from scratch.

Built-in instructional subsystems do not always reflect the results of behavioral science research. The built-in instructional subsystems therefore raise interesting training-research questions, one of which involves the use **"crawl-walk-run" methods--namely, "Under what conditions may** learning be facilitated by the use of alternatives to easy-to-intermediate-to-difficult ('crawl-walk-run') instructional sequences?" Might efficiencies be effected in some cases, for example, by practicing exercises of mixed difficulty from the outset of training, or by practicing only difficult exercises?

Adams (1987), Holding (1962), and others have examined the effects of practicing exercises in three sequences:

1. Easy to difficult.
2. Difficult only.
3. Mixed difficulty.

Easy to Difficult

The Army's "crawl-walk-run" training philosophy (U.S. Army Armor Center, 1985) exemplifies trainers' belief, noted by Jones (1967), that initial training with a simplified version of a task will lead to positive transfer to more difficult versions of the task. Skinner (1953) explained the success of easy-to-difficult training in terms of the importance of early success, which provides continuous reinforcement during early learning of new tasks.

Empirical support for easy-to-difficult instructional sequences is available from research on part-task training (Barton, 1921; Seymour, 1954), programmed instruction (Pressey, 1927; Holding, 1965), and adaptive training (Macrae & Holding, 1965, 1966; Poulton, 1974). Although much evidence supports the efficacy of part-task and other easy-to-difficult training methods, the support is not unequivocal. Gagne and Briggs (1979), for example, acknowledged earlier work on the effectiveness of part-task training, but found no clear advantage for practicing whole or part skills for acquisition. They cited Bilodeau's (1966) contention that part-skill practice does not always lead to more efficient task acquisition.

In summarizing the status of part-task training research, Adams (1987) concluded, "The most bewildering body of literature . . . is the field of part-whole transfer . . . . sometimes whole-task practice was found to be the best, sometimes part-task practice, with no clear principles emerging" (p. 45).

Difficult Only

Training on the criterion or target task is widely accepted as a method for effective transfer (Ellis, 1969). (One might argue that learning, but not transfer, can be demonstrated when the training task and the transfer task are the same, as they are when the criterion task is used in practice. [J. D. Hagman, personal communication, December 1991]). That acceptance is exemplified in the Army's admonition to "train as we will fight" (U.S. Army Training and Doctrine Command, 1990).

Designers of device-based training sometimes strive for "high-fidelity" systems in the belief that the more similar the training system is to the parent system, the greater the training value will be. That belief receives some support from behavioral science research. Thorndike (1913), for example, espoused the existence of "identical elements" in practice and target tasks as the condition for optimal transfer. Identical elements were not well defined, however, so have had little practical effect on training design.

In an experiment by Baker, Wylie, and Gagne (1950), five groups of 31 subjects tracked an irregularly moving target with a pointer controlled by a small hand crank. The rate of crank movement required to track the target was varied among groups and was used as the index of response difficulty. The amount of positive transfer was found to depend upon the similarity of the training and transfer tasks; the greatest amount of transfer occurred when there was no difference between the training and the transfer tasks.

A variation on practicing the criterion is to train on a task that is more difficult than the criterion. Chief advocates of this procedure seem to be sports trainers. Competitive swimmers, for example, may practice while wearing baggy shirts to increase drag, and basketball players sometimes practice with smaller-than-regulation hoops (Ecklund, 1975). Expectations are that athletes who perform adequately under unusually demanding conditions will perform exceptionally under criterion conditions.

Holding (1962) and Wells and Hagman (1989) have hypothesized that initial training on a difficult form of a task may lead to superior transfer or retention than practicing easier forms. Their thinking is that transfer from a difficult form of a task requires no new learning, but that transfer from an easy form requires learning new "task elements." Holding (1962) used his principle of inclusion to explain the effectiveness of difficult-only training for some tasks: If the difficult task includes the easier task, then positive transfer will result.

Gagne and Briggs (1979) advocated whole-part learning, in which trainees learn the total task sequence before practicing individual parts, under some conditions. The whole-part variation on difficult-to-easy practice also was endorsed by Newell (1981), who noted that as a general rule skills should be practiced as wholes; only when whole-skill practice is prohibitively difficult should part-skill practice be used, and then only with meaningful parts.

Mixed Difficulty

Support for the use of exercises of mixed difficulty is found in research demonstrating the benefits of variety in practice. Wolfle (1951), for example, suggested that practice should be varied along the dimensions and range of values over which transfer conditions are expected to vary. He criticized military training during World War II on the grounds that the training material lacked variety, a deficiency that led to rapid acquisition during training, but resulted in poor transfer. Learning did not generalize from original training conditions to the various conditions encountered on the job. Wolfle also noted that variety in practice may slow acquisition, but that benefits would be realized in the range of conditions to which learning would transfer. He added that variety in practice also might counter unwanted effects of monotony.

Schmidt and Bjork (in preparation) addressed how to maximize learning and retention for situations in which several different tasks must be learned in a practice session of fixed duration. They cited research by Shea and Morgan (1979), who compared the effects of two different schedules of practice for learning three motor tasks. In one schedule, the practice trials for each of the three tasks were presented in a logically ordered succession. The other schedule comprised an order of practice trials that was randomized across the three tasks. The randomized schedule yielded inferior performance during initial learning, but better retention, than did practicing the orderly succession of trials for each task. Schmidt and Bjork hypothesized that the random schedule forced trainees to retrieve and organize task information on each trial, and that practicing retrieval led to better retention.

Variables Affecting the Choice of Instructional Method

Some researchers have attempted to organize the considerations discussed above, to develop guidance for using various instructional methods. In his work with sequencing cognitive instruction Briggs (1968), for example, addressed task interdependency: If task elements are independent of one another, then sequencing the elements for instruction is irrelevant; if elements are interdependent, however, then we should train with sequences that reflect the interdependency. Newell's (1981) comments echoed those of Briggs (1968): Trainers should use easy-to-difficult training procedures if task steps are interdependent.

Task type may influence the choice of sequence for easy and difficult practice. Poulton (1974) advocated identifying the most appropriate forms of easy-to-difficult and fixed training methods for a particular task before comparing the two. Both training methods have unique advantages, which may become evident only if training is administered in particular ways or with particular tasks.

Hamilton (1964) indicated that several task and environmental factors influence the effectiveness of instructional method: The factors include response mode, degree of prompting, provision of feedback, and the stability of theme sequence.

Rationale

Theoretical arguments and some empirical evidence support the hypothesis that training efficiency may be increased by training with alternatives to easy-to-difficult sequences. Training with easy or moderate-difficulty tasks may cause trainees to develop habits or strategies that are inefficient or counterproductive when applied to more difficult tasks. Such inappropriate habits could be costly and in some cases dangerous for persons who operate weapons systems. Research to date has not yielded practical guidelines for determining the conditions under which easy-to-difficult, difficult-only, and mixed-difficulty sequences will be most efficient.

In an effort to derive savings that might be realized by using alternatives to traditional training methods, the U.S. Army Research Institute, under sponsorship by the U.S. Army Project Manager for Training Devices, initiated a program of research to identify the conditions under which the use of alternatives to traditional training methods might lead to more efficient learning of psychomotor tasks. The use of alternatives to traditional crawl-walk-run methods was examined in this experiment.

Purpose

The purpose of this experiment was to compare the effects of practicing easy-to-difficult, difficult-only, and mixed-difficulty training sequences on students' scores on a test of mixed-difficulty, simulated gunnery tasks.

Hypothesis

We hypothesized that students trained to track and shoot simulated tank targets, using only difficult targets, would achieve test scores superior to the scores of students who trained using either a progressive, easy-to-difficult set of targets and of students who trained using blocks of trials comprising targets of mixed difficulty. This hypothesis is consistent with Holding's (1962) principle of inclusion, and was based on our belief that, because all practice time for the difficult-only group would be devoted to difficult exercises, the difficult-only group would have much higher scores for the difficult exercises, which when combined with their scores for the easy and intermediate exercises, would yield higher mean scores on mixed-difficulty exercises.

Method

Subjects

Sixty men, aged 19 through 29 years, participated in this experiment. Thirty were unpaid undergraduates from psychology classes at the University of Central Florida (UCF), who received extra course credit for participating; thirty were students from UCF ROTC units, who received no extra course credit, but were paid $5.00 per hour for participating. Ten of the 30 unpaid students and 10 of the 30 paid students were randomly assigned to each of three experimental groups, which were designated PROG, for progressive, or easy-to-intermediate-to-difficult training; DIFF, for difficult-only training; and MIX, for mixed-difficulty training. Each of the three experimental groups thus comprised 20 students, 10 of whom were paid ROTC students, and 10 of whom were unpaid non-ROTC students.

Apparatus

The TOPGUN tank-gunnery training device was used for tracking and shooting simulated tank targets. TOPGUN uses computer-generated imagery to display representations of targets and terrain. Manual controls, similar to those of tanks, allow trainees to track and shoot targets by manipulating aiming reticles and pressing firing buttons. Terrain is represented by narrow colored bands extending horizontally across the CRT display.

TOPGUN exercises of various difficulty were devised for this experiment by programming variations in the speeds and ranges of targets according to the scheme shown in Figure 1. (Speed has been used previously to manipulate difficulty in tracking tasks [Lincoln & Smith, 1951], as has been target range [Green, 1955].) Six speed values were crossed with six range values. The nine combinations of near ranges and slow speeds constituted easy exercises. The nine combinations of near ranges and fast speeds constituted intermediate-difficulty exercises, as did the nine combinations of far ranges and slow speeds. The nine combinations of far ranges and fast speeds constituted difficult exercises.

	NEAR • 1200, 1400, 1600m	FAR • 2000, 2200, 2400m
SLOW • 5, 10, 15 mph	EASY	INTERMEDIATE
FAST • 25, 30, 35mph	INTERMEDIATE	DIFFICULT

Figure 1. Exercise difficulty defined by combinations of target ranges and speeds.

Conduct of the experiment required four different sets of exercises, each set comprising 36 exercises. One set, representing a mix of the three difficulty categories (easy, intermediate, difficult) comprised each of the 36 combinations of 6 ranges and 6 speeds. Separate sets of exercises also were formed, which comprised easy-only, intermediate-only, and difficult-only exercises. The easy-only set of exercises, for example, was formed with four repetitions of each of the nine combinations of range and speed categorized as easy. The sequences of combinations of ranges and speeds were randomized within and across each set of exercises.

Each exercise contained only one target, which was visible to the student for 15 sec. Five-sec breaks intervened between exercises.

The exercises did not contain natural terrain features such as boulders or cultural objects such as houses, which would have concealed targets periodically. The lack of terrain features and cultural objects, and the color differences between targets and terrain made all targets easy to detect. Target range for each exercise was presented on the right of the display, unaccompanied by TOPGUN's optional voice announcement of target range.

Procedure

All students reported to the trailer that housed TOPGUN for approximately 1.5 hour of training and testing. Upon arrival, each completed a consent form (Appendix A) and a background information form (Appendix B), reporting age, grade level, amount of video-game experience, and avowing normal color vision. Students were then randomly assigned to the PROG, DIFF, or MIX groups and were treated as shown in Table 1.

Table 1

Treatment of the Compared Groups (*n* = 20 per group)

	Blocks of 36 Trials			
Group	1	2	3	4 (Test)
PROG	Easy	Intermediate	Difficult	Mixed
DIFF	Difficult	Difficult	Difficult	Mixed
MIX	Mixed	Mixed	Mixed	Mixed

Note. The mixed-target blocks comprised 9 easy, 18 intermediate, and 9 difficult targets presented in random order.

After assigning a student to one of the three treatments, the experimenter administered instructions, which included general information about TOPGUN, how to manipulate the controls, and how to use the sight. (We used the gunner's auxiliary sight or GAS, whose use requires applying various leads to targets depending on their ranges and angles of movement.) The experimenter also told each student that only one round was to be fired at each target (see TOPGUN Instructions, Appendix C; and Script, Appendix D). The student then began the first of three, 36-trial training blocks, the last of which was followed by a 36-trial test block. Each training and test block lasted approximately 12 min, and 5-min rest periods intervened between blocks.

The same experimenter ran all 60 students. He provided feedback about the items listed on the script in Appendix D and corrective feedback to address various errors; if a student consistently overled or underled targets, for example, the experimenter made suggestions for adjusting lead. Students also received, in addition to the visual representations of hits and misses by TOPGUN's graphics system, feedback from TOPGUN, which listed summary performance measures on its screen. These summary measures included total time spent practicing, number of rounds fired, mean times and rounds used to destroy targets, and total numbers of targets destroyed. Students were given no information about how their scores compared to the scores of other students.

Data were coded in three steps: (1) compilation of scores by TOPGUN's performance analysis software; (2) transfer of scores into Lotus 1-2-3 format, to extract usable information and to structure data files; and (3) transfer of Lotus data into SPSS-PC+ format for statistical analyses. All files were inspected for missing data and for anomalies due to equipment malfunctions.

Data were analyzed using _t_-tests comparing Block 1 and Block 3 scores to determine whether learning occurred as a function of treatments; 3 x 2 (group x ROTC/non-ROTC) analyses of variance (ANOVA) to determine whether and how scores differed as functions of treatments and of ROTC membership; 3 x 3 (group x difficulty level) ANOVA to determine whether and how hit percentages and firing times differed as functions of treatments and of exercise difficulty; and Peritz multiple comparisons (Martin and Toothaker, 1989) to determine between which groups differences occurred in cases where group x difficulty-level interactions were significant.

Performance Measures

The speed and accuracy of each trial were measured by time to fire in sec and by azimuth and elevation error in milliradians from center of target mass. Timing for the time-to-fire measure began when automatic slewing of the sight stopped, and ended when the student pressed his firing button. Hit percentages, the number of hits divided by the number of rounds fired in each training and test block (36 in all cases), also were calculated.

TOPGUN provides a choice of three kinds of azimuth and elevation error scores: (1) reticle-aim scores, which are differences in milliradians between reticle placement and target center at the time of firing; (2) lead-error scores, which are deviations from the computer's optimal-lead ballistic solution; and (3) point-of-impact scores, which are the round's vertical and horizontal displacement in milliradians from the target's center at the time of the round's impact. We used point-of-impact scores for four reasons: (1) Reticle aim scores are not appropriate for use with the GAS, whose use requires leading targets; (2) earlier research by Turnage and Bliss (1990) showed TOPGUN's reticle aim scores to be inaccurate and unreliable; (3) pilot testing showed TOPGUN's lead-error scores to be inaccurate; and (4) point-of-impact scores provide comparability with measures of aiming error used in other simulators, such as the Conduct-of-fire Trainers and the Videodisc Gunnery Simulator.

Results

A summary of missing data is in Table 2, where we see that about one-quarter of the azimuth and elevation scores from the three training blocks were missing. Personal communication with the manufacturer of TOPGUN (M. Koziewicz, June 1991) indicated that the scores probably were missing because of problems in TOPGUN's data-recording software.

Table 2

Missing Data for Each Dependent Variable in the Training and Test Blocks

	Training Blocks 1-3		Test Block 4	
Measure	Number	%	Number	%
Target Hits (%)	0/180	0.00	0/60	0.00
Fire Time (sec)	56/6484	0.86	1/2161	0.05
Az. Error (rad/1000)	1627/6484	25.10	259/2161	11.99
El. Error (rad/1000)	1627/6484	25.10	259/2161	11.99

Means based on available scores (without interpolated values for missing data) are shown in Figure 2 for time to fire, in Figure 3 for hit percentage, and in Figures 4 and 5 for elevation error and azimuth error. Standard deviations associated with the means in Figures 2, 3, 4, and 5 are in Appendix E. The MIX and DIFF groups' curves in these figures show similar patterns for all four dependent measures: Mean hit percentages increase, while mean time to fire, mean elevation error, and mean azimuth error decrease across the three training blocks. Means for the PROG group follow a different pattern: Hit percentages decline and times to fire increase over the three training blocks, probably because the targets in Blocks 2 and 3 were farther and moved faster than the targets in the preceding block. Block 4 hit percentages are greater than Block 3 hit percentages for all groups.

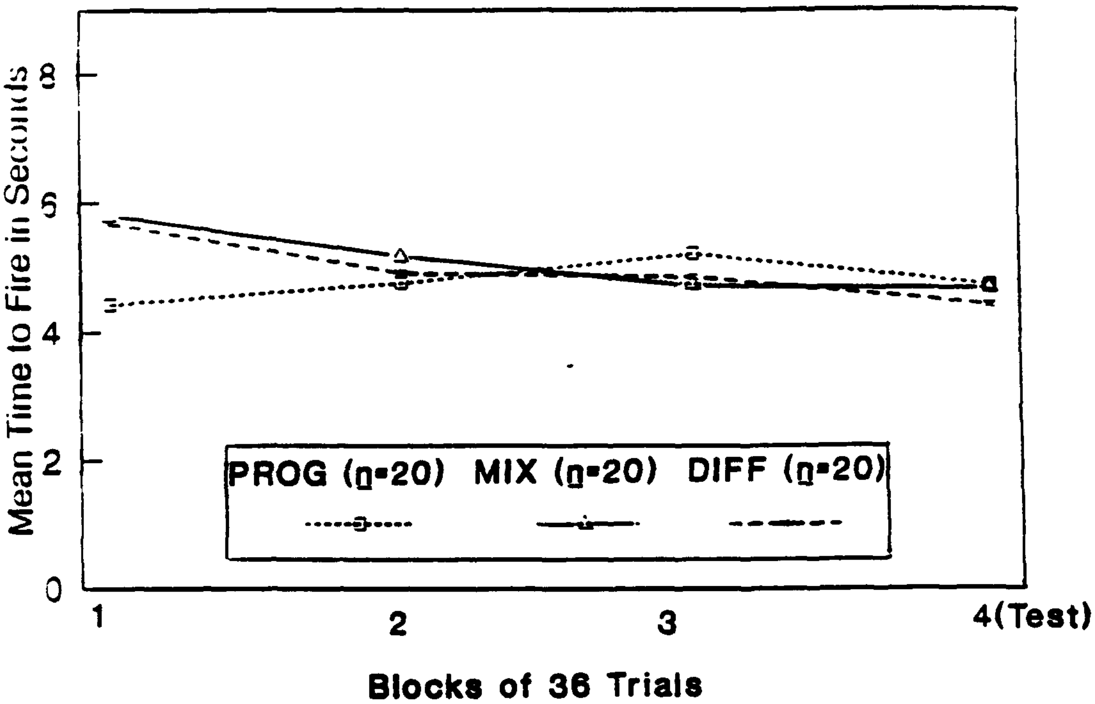

Figure 2. Mean time to fire as a function of practice and test blocks for each group.

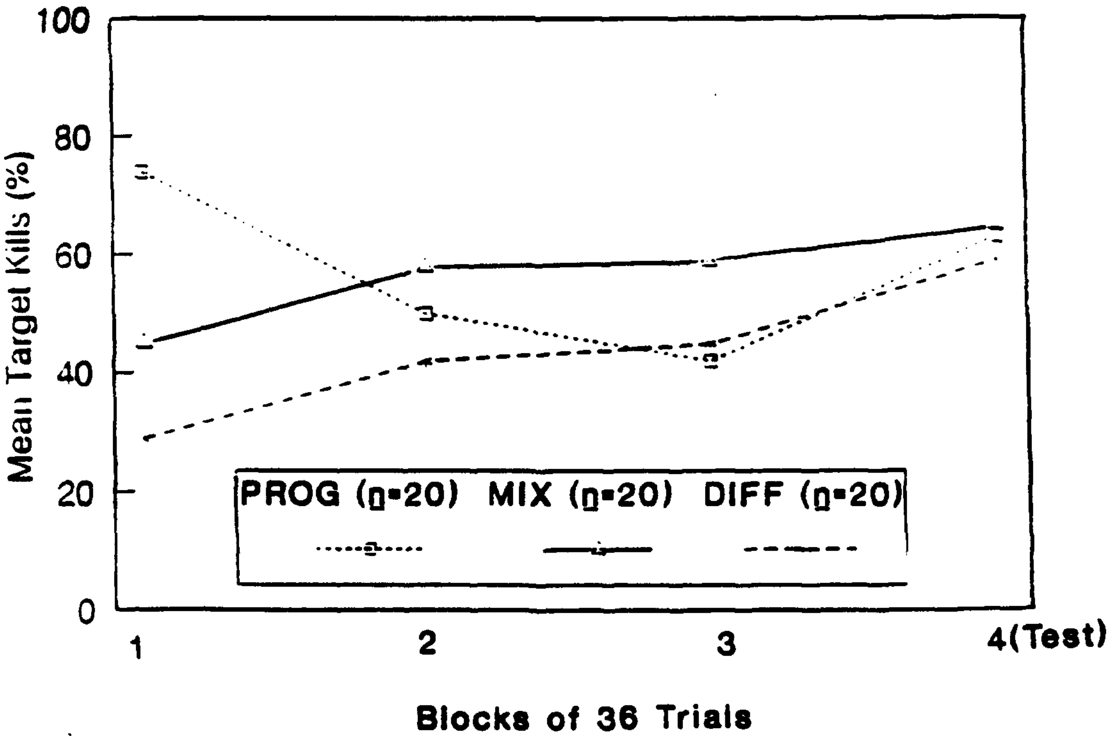

Figure 3. Mean hit percentage as a function of practice and test blocks for each group.

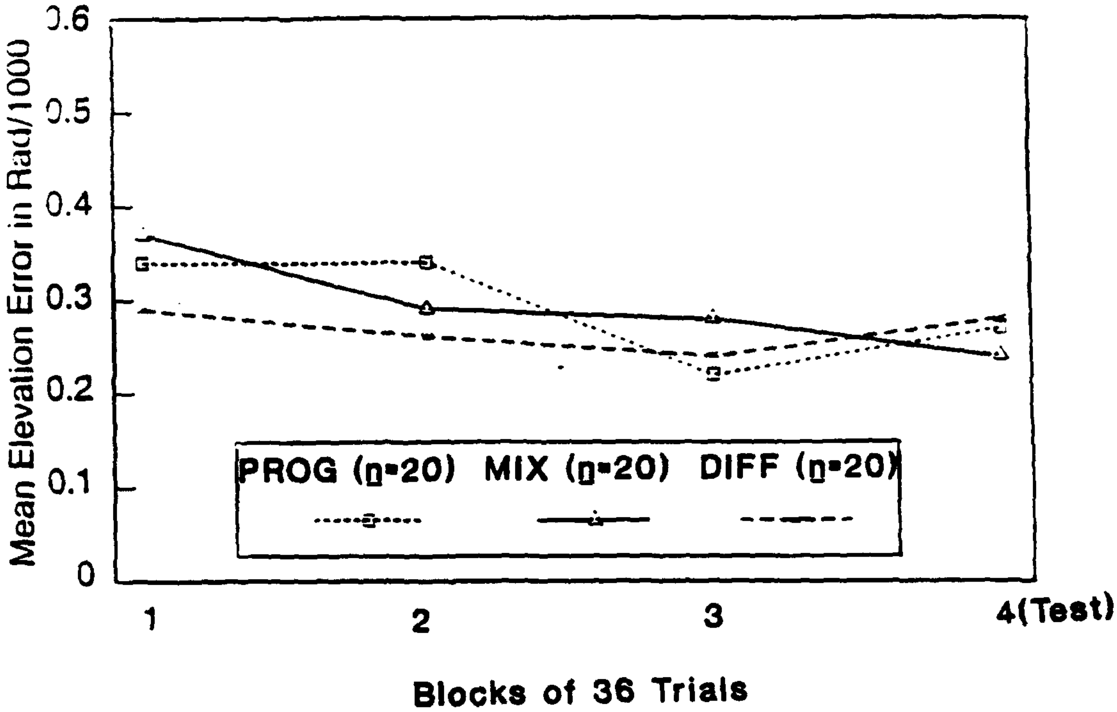

Figure 4. Mean elevation error as a function of practice and test blocks for each group.

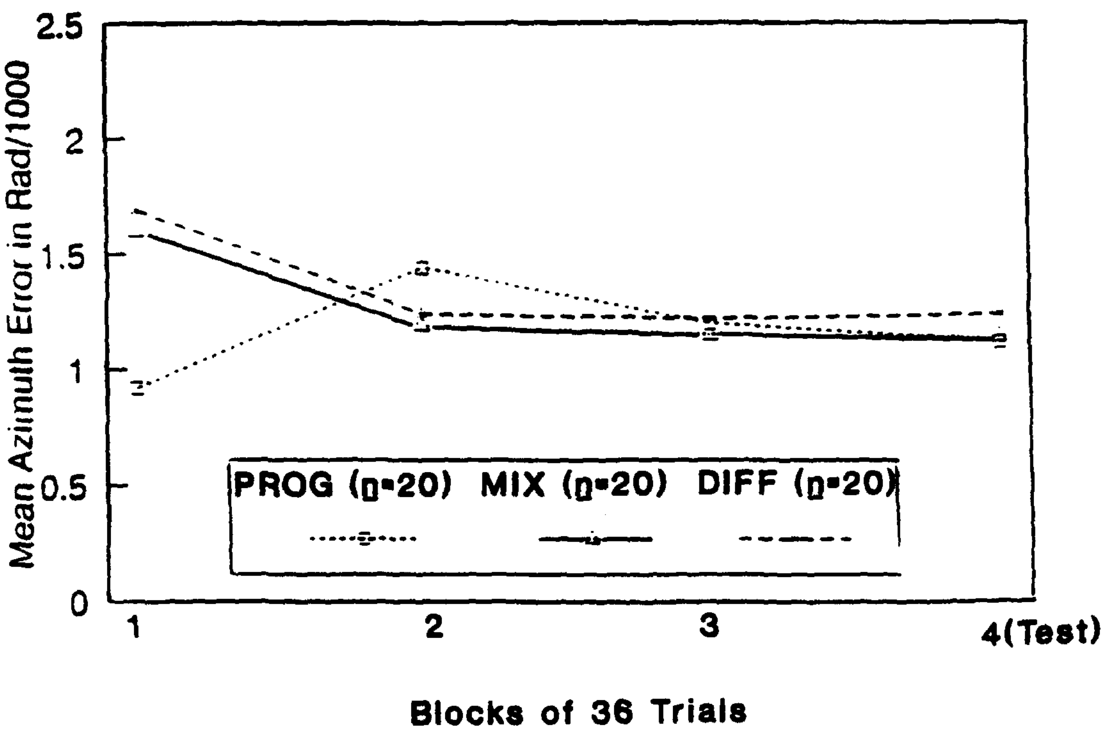

Figure 5. Mean azimuth error as a function of practice and test blocks for each group.

To determine whether learning occurred with practice, we conducted *t*-tests on the differences between Block 1 and Block 3 scores for all four dependent measures, using the MIX group's scores and the DIFF group's scores, but not the PROG group's scores. The reason for not analyzing the differences between the PROG group's Block 1 and Block 3 scores was that the PROG group's Block 3 exercises were more difficult by design than their Block 1 exercises. The results of the *t*-tests are in Tables 3 and 4, where we see that mean scores for all four dependent measures are significantly different between Blocks 1 and 3 for both the MIX and DIFF groups, with all differences in the predicted directions.

Table 3

Results of *t*-Tests (two-tailed, d.f. = 19) between First-block and Third-block Scores for the MIX Group

Measure	Block 1 Mean	Block 3 Mean	t-Value
Target Hits (%)	47.22	59.03	4.27*
Fire Time (sec)	5.79	4.73	-5.08*
Az Er (rad/1000)	1.60	1.15	-6.59*
El Er (rad/1000)	0.37	0.28	-7.17*

* sig. .001

Table 4

Results of *t*-Tests (two-tailed, d.f. = 19) between First-block and Third-block Scores for the DIFF Group

Measure	Block 1 Mean	Block 3 Mean	t-Value
Target Hits (%)	28.75	44.44	6.67*
Fire Time (sec)	5.69	4.85	-4.40*
Az Er (rad/1000)	1.70	1.22	-7.97*
El Er (rad/1000)	0.30	0.24	-2.39*

* sig. .001

Four 3 x 2 (group x ROTC/non-ROTC) analyses of variance were performed on Block 4 test scores to examine the effects of the three treatments and of ROTC membership on each of the four dependent measures. The ANOVA results are summarized in Table 5. In the "Group" column we see that differences due to the three treatments were not significant for any of the four dependent measures.

Table 5

F-Ratios from Analyses of Variance of Block 4 Test Scores as Functions of Group and ROTC/Non-ROTC Membership

Measure	Group	ROTC/ Non-ROTC	Group x ROTC/ Non-ROTC
Target Hits (%)	1.29	7.26*	0.46
Fire Time (sec)	0.49	1.89	0.24
Az. Error (rad/1000)	0.89	5.77*	0.34
El. Error (rad/1000)	2.13	4.56*	0.17

* $p < .05$ (group d.f. = 2, ROTC/non-ROTC d.f. = 1, group x ROTC/non-ROTC d.f. = 2, total d.f. = 59).

The "ROTC/Non-ROTC" column of Table 5 shows *F*-ratios for the effects of ROTC membership. Differences between ROTC students' and non-ROTC students' hit-percentage, azimuth-error, and elevation-error scores are significant, with all differences favoring ROTC membership. The difference between ROTC and non-ROTC students' mean time to fire is not significant.

Interactions between group assignments (treatments) and ROTC membership were examined to determine whether treatments were confounded by differences between ROTC and non-ROTC students' scores. Summaries are shown in the "Group x ROTC/Non ROTC" interaction column of Table 5, where we see that none of the interactions between group assignment and ROTC membership was significant, indicating that ROTC membership did not confound treatments.

Discussion

Our hypothesis, that the DIFF group would achieve better scores on the Block 4 mixed-difficulty test than the PROG and MIX groups would, was not supported by the results of this experiment. Our initial inclination to suggest that the results do not support Holding's (1962) principle of inclusion was dispelled on consideration of what was and was not included in the DIFF group's treatment. The combinations of ranges and speeds of the targets used in the difficult-only treatment did not include the combinations of ranges and speeds of the easy and intermediate targets in the Block 4 mixed-difficulty test. The targets in the difficult-only treatment therefore provided stimuli that precluded learning discriminations among easy, intermediate, and difficult targets -- discriminations that may safely be assumed to be essential for achieving high scores on the Block 4 mixed-difficulty test, which required applying different amounts of lead to targets depending on their speeds and angles of movement. A revised interpretation of Holding's principle of inclusion can thus be made in terms, not of the speeds and ranges subsumed by the speeds and ranges of the most difficult targets, but of inclusion of opportunities to practice the discriminations required for successful performance of mixed-difficulty exercises. The revised interpretation, in retrospect more parsimonious than our original, and which accounts for what is learned during practice, would have led to predicting that (1) the DIFF group would achieve the worst hit percentages and aiming errors on the Block 4 mixed-difficulty test, because the DIFF group received no prior opportunity to practice discriminating among easy, intermediate, and difficult targets; (2) the MIX group would achieve the best hit percentages and aiming errors on the Block 4 mixed-difficulty test, because the MIX group practiced discriminating among easy, intermediate, and difficult targets throughout training; and (3) the PROG group would achieve better hit percentages and aiming errors than the DIFF group's but worse than the MIX group's on the Block 4 mixed-difficulty test, because the PROG group's learning discriminations among easy, intermediate, and difficult targets depended upon remembering how targets and leads differed among the three training blocks. Thus, according to our revised interpretation of Holding's principle of inclusion, the ordering of the three groups' Block 4 hit-percentage and aiming-error scores should be MIX best, PROG next-best, and DIFF worst. An exception to that order should occur in time to fire: The DIFF group should have the fastest mean firing time on the Block 4 mixed-difficulty test, because the shooters would save time by not making the discriminations necessary to apply various leads before firing -- or at least would make fewer discriminations than the MIX and PROG groups would make.

A similar ordering of the compared groups' hit percentages and aiming errors -- MIX best, PROG next-best, DIFF worst -- results from predictions based on the similarity and the order of presentation between the Block 4 test items on the one hand, and the items practiced by the three groups in Blocks 1, 2, and 3 on the other: Similarity between practice items and test items, and between order of presentation (random during practice and random during testing) was greatest for the MIX group, next greatest for the PROG group (non-random order of presentation), and least for the DIFF group (no practice with easy and intermediate targets). Unlike the firing-time prediction from the revised principle of inclusion presented above, the prediction from a hypothesis based on similarity of test items and practice items is that the DIFF group would have slower mean firing times than the MIX and DIFF groups on the test, because the test items were more similar to the MIX and PROG groups' practice items than they were to the DIFF group's practice items.

Notwithstanding the absence of statistically significant between-group differences in this experiment, our revised principle-of-inclusion hypothesis and the test-practice similarity hypotheses presented above are better supported by the data than was our original principle-of-inclusion hypothesis: The order of the compared groups' scores in terms of percentage hits and elevation error (see Appendix E) was MIX best, PROG next-best, DIFF worst. (An exception to the revised prediction occurred in azimuth error because of a difference of two one-hundredths of a milliradian between the MIX and PROG groups.) In terms of firing time, DIFF was best, MIX next-best, PROG worst. Predictions from both hypotheses, one based on our revised principle of inclusion and the other based on similarity between test items and practice items, are thus supported by the hit-percentage and aiming-error data. As for firing time, however, the revised principle-of-inclusion hypothesis leads to predicting correctly the DIFF group's shooting faster than the MIX and PROG groups, and the test-practice similarity hypothesis does not.

Although no differences were found among the groups' scores on the Block 4 mixed-difficulty test, the possibility remained that the three treatments differentially affected each group's scores on the easy, intermediate, and difficult exercises in Block 4. That possibility is addressed in Figures 6 and 7, where mean hit percentages and mean firing times are shown as functions of the three levels of exercise difficulty constituting the Block 4 test. We see in Figure 6 that, contrary to our original hypothesis, the DIFF group's mean hit percentage fell between the mean hit percentages of the PROG and MIX groups on the difficult exercises in the test. Consistent with our original hypothesis, however, the DIFF group did achieve faster mean firing times than did the other two groups on the difficult exercises in the Block 4 test (see Figure 7).

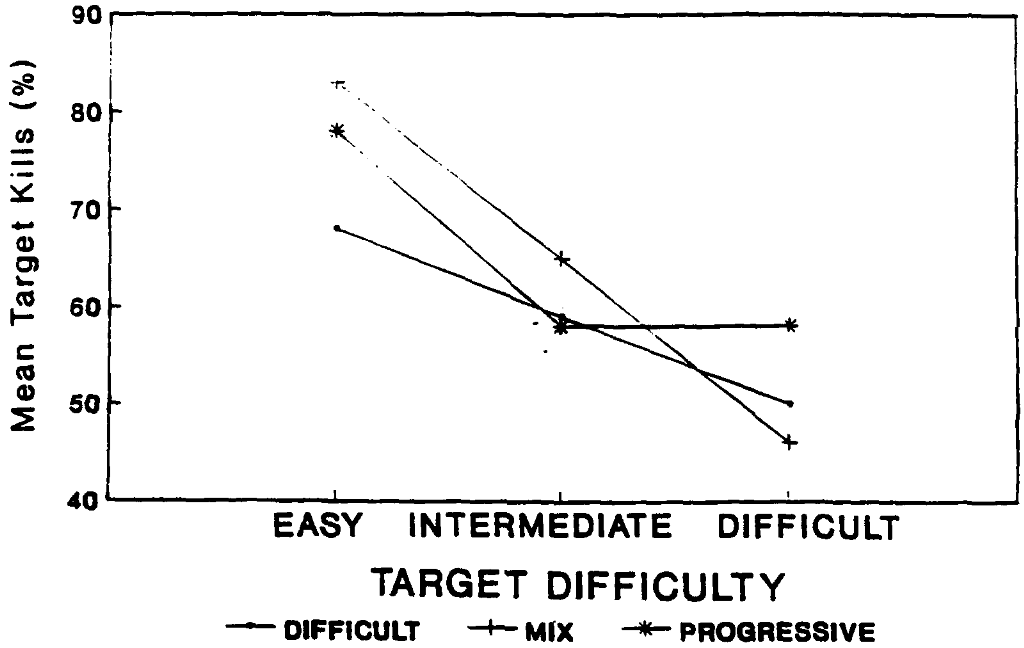

Figure 6. Mean hit percentage for the Block 4 test as a function of exercise difficulty.

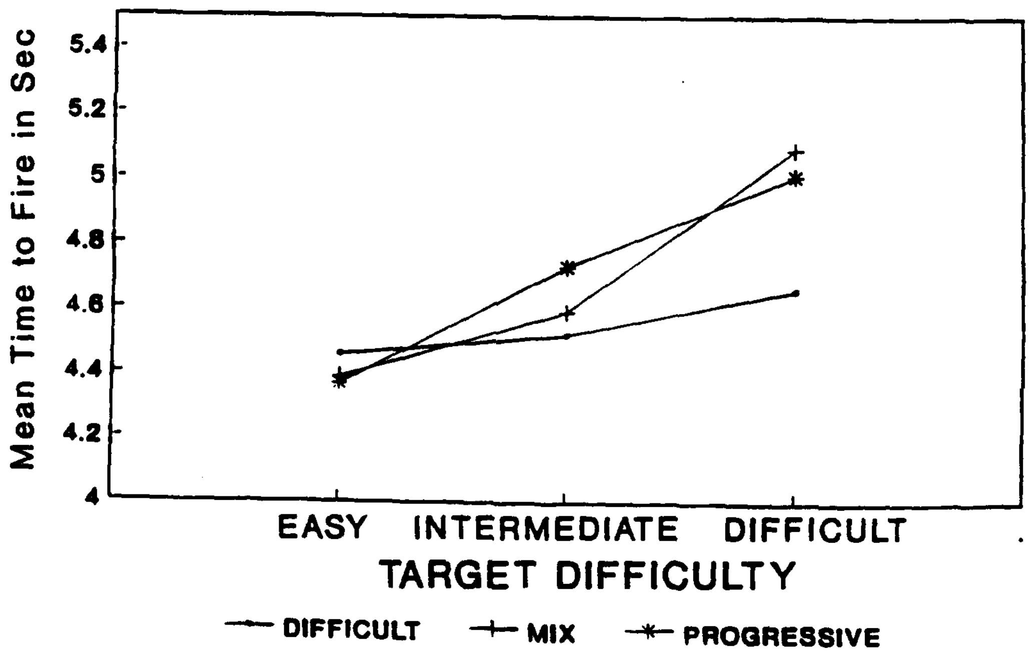

Figure 7. Mean time to fire for the Block 4 test as a function of category of exercise difficulty.

Three x three (group x difficulty level) analyses of variance were performed on the data in Figures 6 and 7 to determine the separate and interactive effects of treatments and exercise difficulty on Block 4 hit percentages and times to fire. Summaries of the analyses are in Table 6, where once again (cf. Table 5) we see no significant differences as functions of group assignment for either hit percentages or firing times. Differences in both hit percentages and firing times are significant as functions of difficulty level, however, suggesting that our definitions of exercise difficulty in terms of target range and speed were valid.

Table 6

Analysis-of-variance Summaries: Target Hits and Times to Fire as Functions of Group and Difficulty Levels of Block 4 Test Exercises

Source (Hit %)	SS	DF	MS	F
Group	0.13	2	0.06	1.20
Difficulty Level	1.97	2	0.98	61.24*
Group x Diff. Level	0.33	4	0.08	5.15*
Source (Fire Time Sec)				
Group	0.84	2	0.42	0.11
Difficulty Level	8.00	2	4.00	16.52*
Group x Diff. Level	1.74	4	0.43	1.79

* sig. .001

Table 6 also shows a significant group x exercise-difficulty interaction for hit percentage, but not for firing time; that is, the treatments differentially affected the compared groups' hit percentages, but not their firing times, on easy, intermediate, and difficult exercises.

Results of Peritz multiple comparisons (Martin and Toothaker, 1989) of hit rates as functions of group assignment and of Block 4 target-difficulty levels are shown in Table 7, where we see that three of the nine possible within-difficulty, pair-wise comparisons are significant (with $\underline{a} = .05$). The two significant differences between hit percentages on easy targets, MIX > DIFF and PROG > DIFF, are easy to explain: Both the MIX and PROG groups had practiced easy, intermediate, and difficult exercises before taking the Block 4 mixed-difficulty test. The MIX and PROG groups therefore had opportunities to learn the discriminations necessary for applying different leads to easy, intermediate, and difficult targets. Learning those discriminations allowed the MIX and PROG groups to hit a greater percentage of the easy targets on the Block 4 test than did the DIFF group, which had no prior opportunity to practice the discriminations.

Table 7

Results of Peritz Multiple Comparisons: Target Hits as Functions of Group and Difficulty Levels of Block 4 Test Exercises

	Difficulty of Exercises in Block 4:		
Comparisons	Easy	Intermed.	Difficult
MIX v. DIFF	MIX>DIFF*	n.s.	n.s.
PROG v. DIFF	PROG>DIFF*	n.s.	n.s.
PROG v. MIX	n.s.	n.s.	PROG>MIX*

*$\underline{a}$ = .05

The PROG group's achieving a significantly greater hit percentage than the MIX group on the difficult exercises in the Block 4 test is more difficult to explain. A hypothesis in terms of amounts and recency of practice does, however, seem tenable: Before taking the Block 4 mixed-difficulty test, the MIX group practiced 27 trials against difficult targets -- nine in each of the three training blocks (see Table 1). Before taking the Block 4 mixed-difficulty test, the PROG group practiced 36 trials against difficult targets -- all 36 during Block 3. The PROG group thus practiced a greater number of difficult exercises more recently than did the MIX group. If the PROG group persevered during Block 4 in applying the leads they used while practicing the 36 exclusively difficult exercises in Block 3, we would expect the PROG group to score higher against the difficult targets (and lower against intermediate and easy targets) in Block 4 than the MIX group would (see Figure 6). A similar explanation is not applicable to the DIFF group (which practiced the same number of difficult exercises as the PROG group did immediately before testing), because of interfering effects of the intermediate and easy targets encountered for the first time in Block 4. The DIFF group thus not only failed to achieve superior overall hit percentages on the Block 4 test of mixed-difficulty exercises, but also failed to achieve superior scores for the difficult test exercises in Block 4. Those results are especially puzzling on comparing Block 3 hit percentages (see Figure 3 and

Appendix E) for the PROG and DIFF groups: During Block 3, both the PROG group and the DIFF group practiced the same set of difficult-only exercises, on which the DIFF group scored 45% hits and the PROG group 42%; that is, by the end of Block 3 the PROG group did not achieve a greater hit percentage than did the DIFF group. On Block 4, however, the DIFF group scored 50% against difficult targets (see Figure 6), as compared to 45% against Block 3 difficult-only targets. Thus, even though the DIFF group continued to improve their hit percentages against difficult targets during Block 4 testing, the possibilities remain that (1) they would have improved even more in the absence of the intermediate and easy targets' interfering effects (J. D. Hagman, personal communication, December, 1991), and (2) they may have surpassed the PROG group in a longer test of mixed-difficulty exercises. That second possibility is related to a larger, unresolved issue that bears on the results of this and other training research. The issue is when to measure training effects and relates to our using end-of-training test scores without measures of transfer and retention as dependent measures. That training methods may have differential effects on initial learning, transfer, and retention is well known. Gagne (1954), for example, discussed the importance of measuring effects at various intervals after training, because of likely changes in the direction and slope of transfer and generalization functions over time.

In a recent discussion of differential training effects on initial learning and retention, Wells and Hagman (1989) compared the merits of two strategies for teaching a mixed set of tasks: In one strategy, blocking similar tasks together during practice may speed initial learning. Doing so corresponds to the pattern of practice used in the present experiment by the PROG group. The second strategy is to practice dissimilar tasks mixed within blocks. This strategy, which corresponds to the treatment of our MIX group, was hypothesized by Wells and Hagman to improve retention. It is possible that each of the three strategies used in the present research had strengths and weaknesses such that none proved superior to the others only in terms of test scores obtained immediately after training. That possibility should be pursued by investigating differential effects of various training methods or strategies on initial learning, transfer, retention, and generalization.

Summary and Implications

Practicing easy-to-difficult, difficult-only, or randomly ordered, mixed-difficulty training exercises effected no significant differences in target hits, times to fire, and aiming errors on a test of randomly ordered, mixed-difficulty exercises administered immediately after training. The easy-to-difficult and the mixed-difficulty treatments did, however, result in significantly greater hit percentages against easy targets than did the difficult-only treatment; and the easy-to-difficult treatment resulted in significantly greater hit percentages against difficult targets than did the mixed-difficulty treatment.

Several hypotheses and <u>post</u> <u>facto</u> explanations of the results were offered; their tenability can be established in light of additional research results. In the meantime one implication for military training remains as Wolfle suggested in 1951: Practice should vary along the dimensions and range of values over which transfer conditions are expected to vary. Varied practice seems especially germane to training for situations in which we have less than complete knowledge about the characteristics of target arrays that will be encountered in combat. Training exercises should be juxtaposed in ways that promote, not only proficiency on each exercise, but also learning the discriminations necessary for proficiency in the face of novelty and variety. Exact strategies for optimizing efficiencies among acquisition, retention, transfer, and generalization, however, remain to be discovered.

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APPENDIX A

Consent Form and Volunteer Agreement, Side 1

I, ____, having full capacity to consent, do hereby volunteer to participate in research entitled Training efficacy as a function of instructional strategy under supervision of the US Army Research Institute. The implications of my voluntary participation and the nature, duration, and purpose of the research, and the method and means by which it is to be conducted are contained on the reverse side of this form. I have been given an opportunity to read and keep a copy of this Agreement and to ask questions concerning this research. Any such questions have been answered to my full and complete satisfaction. Should any further questions arise, I will be able to contact Don Lampton at 380-4368. I understand that I may at any time during this research revoke my consent and withdraw from the test without prejudice, but I will not be paid unless I complete 2 full hours.

____

(Signature, Date)

I was present during the explanations referred to above as well as the volunteer's opportunity for questions and hereby witness his signature.

______________________________ ______________________

(Witness) (Date)

APPENDIX A (continued)

Consent Form and Volunteer Agreement, Side 2

For many educational, industrial and military applications computer-based training simulations provide an inexpensive and safe complement to training with operational systems and equipment. This experiment is part of a project to develop better methods of training with simulators. The purpose of this experiment is to evaluate training effectiveness as a function of the sequence of exercise difficulty.

You will be asked to practice an aiming task using a computer-based training simulator which was developed to train tank gunnery. You will aim and fire at a series of targets. After each shot you will receive an indication of whether you hit or missed. The task involves using manual controls to track a target. (The device display and the required task are somewhat similar to the displays and tasks used for many video games.) After an initial practice period you will complete 4 sessions of tracking tasks. Each session will consist of approximately 20 targets. The speed and range of targets may vary across sessions.

Schedule:

Time	Activity
00 - 15 minutes	orientation
15 - 20 minutes	practice
20 - 40 minutes	session I
40 - 45 minutes	break
45 - 65 minutes	session II
65 - 70 minutes	break
70 - 90 minutes	session III
90 - 95 minutes	break
95 - 115 minutes	session IV
115 - 120 minutes	debriefing/payment

The risks involved are those associated with viewing standard video display screens.

You are free to terminate participation in this experiment at any time without bias. However, you will not be paid unless you complete the 2 hour session.

Do you have any questions?

APPENDIX B

Background Information

The purpose of this questionnaire is to collect background information on participants in the ARI simulator training research. This information will be used strictly for research purposes only. Please complete each item to the best of your ability. Write "N/A" for each item you cannot answer.

1. Name:____
   Last First M.I.

2. Social Security Number:______-______-_______

3. Date of Birth:_____/____/_____

4. Present grade classification (Junior, Senior, etc.)______________

5. How often do you play video games (circle one)?

   A. less than once per week
   B. once per week
   C. 2-4 times a week
   D. greater than 4 times/week

6. Have you ever been diagnosed as color blind/deficient?______

APPENDIX C

Instructions

Hello. My name is Jim Bliss with the Army Research Institute. Today you will train for approximately 2 hours on the TOPGUN tank gunnery trainer. Please seat yourself inside the trainer. You are seated inside a trainer for the gunner position of the M1 tank. It is a relatively simple device; much like a video game.

In front of you, you will see two connected handles. These handles move the gun tube up, down, and side to side. To move the aiming crosshairs side to side, turn the handle like a steering wheel. To move the crosshairs up or down, twist the handles accordingly (demonstrate). You will notice a set of buttons located near the index fingers' position. These are the fire buttons that you will use to destroy enemy targets. Most importantly, in order for any buttons or handle movement controls to operate, **THE PALM LEVERS ON THE FRONT OF THE HANDLES MUST BE ENGAGED!!!**

During the following engagements, you will use the crosshairs shown below. When the automated tank commander moves you to the target, you must immediately estimate and implement the proper amount of horizontal and vertical "lead" required to hit the target. Horizontal lead means you must aim in front of a moving target; Vertical lead means you must aim above distant targets. You will have help with vertical lead; when a target is presented, you will see a corresponding range figure appear in the window. The numbers on the side of the reticle correspond to the range of round impact; therefore, you must position the reticle so that the correct range is on the target when you fire.
Example: If a target is determined to be 1600 meters away, you should put the center of the line beside "16" on the target if it is stationary, or just in front of the target if it is moving. Then squeeze the fire button.

```
                --------|--------
----------         -----------8
.     ---------0--------      .   12
----------         -----------16
.     -----------------       .   20
----------         -----------24
         .        .               28
```

When engaging a target, the sequence of activities is as follows: 1) **Squeeze the palm levers and hold them down,** 2) After the tank commander slews you toward the target, estimate the amount of horizontal and vertical lead required to effectively engage the target, 3) Position the crosshairs at the proper position relative to the target, 4) Press the fire button, and, finally, 5) Continue monitoring the target until the round falls. Then, quit firing and wait for the next target. Only 1 round per target is permitted.

APPENDIX D

Target Engagement Script

The following items should be mentioned to trainees:

1) We'd like you to aim for the very center of the target; also, we'd like you to be as quick as possible. Therefore, speed and accuracy are equally important.

2) You'll notice that the range figures are quite exact; so, if the range to a target is 1600 meters, for example, you need to position the crosshairs accordingly or you <u>will miss</u>.

3) Occasionally a round may <u>look</u> like it hit the target, but credit is not given. This usually means that the round landed just beyond the target.

4) When you engage targets on an incline or decline, you must anticipate their vertical movement; so if a target is at 1400 meters and moving uphill, you should position the crosshairs at 1600 meters, to effectively anticipate the target's upward movement.

5) You'll notice that the range figure takes a split second to update when a new target is presented; therefore, you should make certain of the range before firing.

The following should be said between target sets (blocks).

1) Now, I'd like you to lean back and shut your eyes, giving them a chance to rest from the screen; also, move your hands around, since the controls are somewhat stiff.

2) OK, the basic task is the same as before. Remember, speed and accuracy are equally important. When you feel rested, hit the fire button to begin.

APPENDIX E

Means and Standard Deviations ( )
for the Compared Groups' Scores

Measure	Group	Block 1	Block 2	Block 3	Block 4
TFIRE in sec.	PROG	4.34 (1.22)	4.76 (1.32)	5.21 (1.32)	4.71 (1.05)
	DIFF	5.68 (1.31)	4.91 (1.44)	4.85 (1.51)	4.40 (1.18)
	MIX	5.79 (1.38)	5.16 (1.12)	4.73 (1.00)	4.66 (0.91)
HIT (.00)	PROG	0.74 (0.10)	0.50 (0.11)	0.42 (0.14)	0.63 (0.16)
	DIFF	0.29 (0.11)	0.42 (0.13)	0.45 (0.13)	0.59 (0.14)
	MIX	0.47 (0.12)	0.58 (0.10)	0.59 (0.09)	0.65 (0.09)
AZ Error in Rad/1000	PROG	0.92 (0.19)	1.44 (0.37)	1.20 (0.30)	1.12 (0.29)
	DIFF	1.69 (0.40)	1.24 (0.35)	1.22 (0.31)	1.24 (0.37)
	MIX	1.60 (0.33)	1.19 (0.25)	1.15 (0.23)	1.14 (0.26)
EL Error in Rad/1000	PROG	0.34 (0.05)	0.34 (0.05)	0.22 (0.05)	0.27 (0.07)
	DIFF	0.29 (0.05)	0.26 (0.07)	0.24 (0.07)	0.28 (0.04)
	MIX	0.37 (0.05)	0.29 (0.04)	0.28 (0.05)	0.24 (0.05)

Note: The PROG group does not show a typical learning pattern, because target difficulty increased across the three training blocks.