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The Effects of Amount of MI Unit Conduct-of-Fire Trainer (U-COFT) Transition Training on Crew Gunnery Proficiency

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The Effects of Amount of M1 Unit Conduct-of-Fire Trainer (U-COFT) Transition Training on Crew Gunnery Proficiency

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This research examined the effects of three types of variables on crew M1 Unit Conduct-of-Fire (U-COFT) gunnery proficiency during transition training: time spent training on the M1 U-COFT, soldier-based variables (e.g., time with partner, time in armor), and training-based variables (e.g., classroom hours, time spent on the M60A3 U-COFT). The reliability of the gunnery proficiency test was also assessed. Three groups of TC-gunner teams were tested after having completed 3, 6, or 9 hours of transition training on the M1 U-COFT. Time spent on the U-COFT resulted in improved gunnery performance on only one of seven criterion measures--average miss distance. Since this was the most sensitive measure of gunnery performance, the results suggest that learning may have taken place despite the failure to detect performance improvements on six of the seven criterion measures. Although the three groups differed significantly on a number of training-based variables, only the number of exercises completed in the TC training matrix had an effect on any of the performance measures. The reliability of all of the criterion measures exceeded 0.50, with the reliability of two measures exceeding 0.70.

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FOREWORD

The development of an effective training strategy for crew gunnery requires information on the relationship between practice on gunnery simulators and skill acquisition. Although the M1 Unit Conduct-of-Fire Trainer (U-COFT) is used for training crew gunnery skills, the rate at which these skills are acquired has not been documented. As a consequence, there is uncertainty over the optimal amount of U-COFT practice necessary for effective training.

This research examines the effects of U-COFT practice during transition training from the M60A3 to the M1 tank. The research is part of the Army Research Institute for the Behavioral and Social Sciences (ARI) task entitled "Application of Technology to Meet Armor Skills Training Needs." The task is performed under the auspices of ARI's Armor Research and Development Activity at Fort Knox.

The research was performed in response to a request from the Deputy Chief of Staff for Training (DCST), U.S. Army Training and Doctrine Command (TRADOC). At the request of the DCST, the information presented in this report was provided to the Chief, Training Research and Studies Division, Training Developments Analysis Directorate, DCST, and to the Unit Training Effectiveness Analysis Directorate at TRAC-WSMR. The information was also provided to the Armor Simulation Division of the Weapons Department, U.S. Army Armor School, Fort Knox.

The proponent for this research is U.S. Training and Doctrine Command.

THE EFFECTS OF AMOUNT OF M1 UNIT CONDUCT-OF-FIRE TRAINER (U-COFT) TRANSITION TRAINING ON CREW GUNNERY PROFICIENCY

EXECUTIVE SUMMARY

Requirement:

The purpose of the present research was to determine the relationship between amount of practice on the M1 Unit Conduct-of-Fire Trainer (U-COFT) and the acquisition of crew gunnery skills during transition training.

Procedure:

Sixty-eight tank crews transitioning from the M60A3 to the M1 tank participated in the study. A gunnery proficiency test was administered on the U-COFT to each crew after 3, 6, or 9 hours of U-COFT practice. The test consisted of four U-COFT exercises reflecting the conditions involved in Table VIII. In addition, biographical data were obtained from each participant, along with information on the amount of transition training that each had received.

Findings:

Increasing the number of hours of transition training on M1 U-COFT resulted in improved gunnery performance on only one criterion measure: average miss distance. Further analyses were conducted to determine if the failure to find additional relationships could have been due to prior U-COFT experience or the predominance of moving tank engagements on the criterion test. Both factors were eliminated as likely causes for the failure to find positive relationships between amount of M1 U-COFT transition training and the other measures of gunnery proficiency. Since earlier research had suggested that average miss distance is the most sensitive measure of gunnery proficiency, the results appear to suggest that skill acquisition did occur during transition training, but that further training was needed.

Use of Findings:

The results of this study can be used in the development of training schedules for M1 U-COFT during the transition from the M60A3 tank to the M1.

THE EFFECTS OF AMOUNT OF M1 UNIT CONDUCT-OF-FIRE TRAINER (U-COFT) TRANSITION TRAINING ON CREW GUNNERY PROFICIENCY

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THE EFFECTS OF AMOUNT OF M1 UNIT CONDUCT-OF-FIRE TRAINER (U-COFT) TRANSITION TRAINING ON CREW GUNNERY PROFICIENCY

Introduction

The Army has been striving to optimize the gunnery proficiency of tank crews while maintaining cost-effective training and testing methods. Many hours of hands-on practice are required before tank crews become adept at engaging enemy targets quickly and accurately. However, teaching the appropriate gunnery skills to armor crewmen using live ammunition is costly. As a result, the U. S. Army Armor School has become increasingly reliant on tank gunnery training devices that enable tank crews to practice engagements while conserving expensive ammunition.

As early as 1979, there existed 21 tank-appended or stand-alone devices for training gunnery skills for the M60A1 tank (Fingerman, Wheaton, & Boycan, 1979). While the majority of those devices identified by Fingerman et al. are tank-appended, the complexity and escalating cost of simply operating an M1 tank, even without firing live rounds, has forced the Army to expand the use of stand-alone devices. As the emphasis on such devices has increased in recent years, advances in technology have made possible sophisticated computer-based devices that are able to simulate large portions of the tank gunnery domain.

One of the most frequently used stand-alone gunnery training devices is the Unit Conduct-of-Fire Trainer (U-COFT). This report describes the results of research on a number of issues relating training on the M1 U-COFT to performance on a U-COFT-based test of M1 gunnery proficiency.

U-COFT Training Strategy

The M1 U-COFT is an armor gunnery simulator that was developed to train tank commanders (TCs) and gunners. The U-COFT contains simulated TC and gunner crew stations and presents computer-generated images of targets in the TC and gunner sights. The TC-gunner teams, or crews[1], are instructed to go through the actual engagement procedures necessary to produce simulated target "kills."

The Armor School field circular entitled M1 Unit Conduct-of-Fire Trainer (U-COFT) Training Devices Support Package (FC 17-12-7-1, 1985) identifies four types of gunnery training that are supported by U-COFT programs: (a) basic gunnery training of non-armor personnel so that they can serve as battlefield replacements; (b) transition training of tank crewmen who are converting from

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[1]Throughout the remainder of this report, the term "crew" will refer to the TC and gunner only since the U-COFT is configured to train only those two crew positions.

the M60 to the M1 tank; (c) cross training of M1 drivers and loaders in the gunner's position or of gunners in the TC's position; and (d) sustainment training for TCs and gunners with M1 experience.

The U-COFT contains 685 training exercises that cover a broad range of target engagement situations by simulating a variety of tactical situations, weather and visibility conditions, and levels of equipment readiness. Each exercise contains from four to ten engagements. Exercises on U-COFT are controlled by an instructor/operator (I/O) whose responsibilities include initiating the exercise, acting as the driver and loader, monitoring the crew's performance, and providing performance feedback to the crew.

As detailed in the Instructor's Utilization Handbook for the M1 U-COFT (1985), the exercises on U-COFT are organized into two matrices, one for the TC/gunner team and one for the TC alone, as shown in Appendix A. Each matrix represents the following three gunnery skill dimensions or areas: (a) target acquisition (skills necessary to acquire and identify targets), (b) reticle aim (skills necessary to aim and fire at targets), and (c) system management (skills necessary to operate the fire control systems). Each of the three skill areas is broken into levels of increasing difficulty as shown in Tables 1 and 2. Each exercise within a matrix is identified by an exercise number. This exercise number provides information regarding the matrix from which the exercise was selected as well as the system management, target acquisition, and reticle aim levels of the exercise. For example, crews begin transition training on the M1 U-COFT by firing exercise number 32111; this indicates that the exercise is located within the TC/gunner matrix, at system management level 2, reticle aim group 1, reticle aim difficulty level 1 within the specified reticle aim group, and target acquisition level 1. Table 3 details the components of exercise number 32111, while the position of that exercise within the TC/gunner matrix is shown in Appendix A, Figure A-2.

As crews work their way through each of the matrix dimensions, the U-COFT computer controls progress through the training matrices by selecting exercises based on the crew's previous U-COFT performance. After each exercise is fired, the computer calculates an average score for each skill area. This score is used as the basis for a "progress recommendation" provided by the computer. Four progress recommendations are possible for each skill area: (a) rapid advance, (b) normal advance, (c) no advance, and (d) reduction. The computer uses these progress recommendations to regulate crew advancement through the different levels within each skill area by determining the exercise to be fired next. The matrix movement rules, which are presented in Table 4, prevent crews from moving through each matrix before they have mastered the skills represented by a particular skill area.

In both matrices, crews must show proficiency in all three skill areas on a "gate" exercise within each reticle aim group in order to advance to the next reticle aim group. For crews in transition training, the gate exercise in the TC/gunner matrix is the most difficult NBC exercise within each reticle aim group. In the TC matrix, the gate exercise for each reticle aim group is the most difficult exercise containing no weapon system malfunctions. The positions of the gate exercises within each matrix are shown in Appendix A.

Table 1

Difficulty Levels within U-COFT Gunnery Skill Areas: TC/Gunner Matrix

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Target Acquisition - three levels of decreasing visibility.

Level 1: a. Day; unlimited visibility conditions.

b. Night; unlimited visibility conditions using thermal mode.

Level 2: a. Dawn/Dusk; reduced visibility conditions.

b. Night visibility conditions using thermal mode; thermal clutter added to increase difficulty.

c. Day fog visibility conditions; thermal clutter added to increase difficulty.

Level 3: a. Day; hazy or limited visibility conditions; simulated dust and smoke from friendly and threat fire added to increase difficulty.

b. Night visibility conditions using thermal mode; simulated dust and smoke form friendly and threat fire; thermal clutter added to increase difficulty.

Reticle Aim - 39 levels of difficulty in six groups; difficulty increased by introducing equipment malfunctions into the exercises and changing the movement of the own vehicle and targets.

Group 1: Seven difficulty levels featuring stationary own vehicle and stationary tank targets.

Group 2: Seven difficulty levels featuring stationary own vehicle and stationary targets.

Group 3: Seven difficulty levels featuring stationary own vehicle and moving targets.

Group 4: Seven difficulty levels featuring moving own vehicle and stationary targets.

Group 5: Seven difficulty levels featuring moving own vehicle and moving targets; contains a certification exercise that must be passed.

Group 6: Four difficulty levels featuring stationary and moving own vehicle, stationary and moving targets; contains certification exercise that must be passed.

System Management - four levels of difficulty; difficulty increased by changing the range to the targets.

Level 1: Single targets at short range.

Level 2: Single targets at long range.

Level 3: Multiple targets at short range.

Level 4: Multiple targets at long range

Table 2

Difficulty Levels within U-COFT Gunnery Skill Areas: TC Matrix

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Target Acquisition - three levels of decreasing visibility.

Level 1: Day; unlimited visibility conditions.

Level 2: Dawn/Dusk; reduced visibility conditions.

Level 3: Day; hazy or limited visibility conditions, including simulated dust and smoke from friendly and threat fire.

Reticle Aim - 21 levels of difficulty in five groups; difficulty increased by introducing equipment malfunctions into the exercises and changing the movement of the own venicle and targets.

Group 1: Five difficulty levels featuring stationary own vehicle and stationary tank targets.

Group 2: Five difficulty levels featuring stationary own vehicle and stationary targets.

Group 3: Five difficulty levels featuring stationary own vehicle and moving targets.

Group 4: Three difficulty levels featuring moving own vehicle and stationary targets.

Group 5: Three difficulty levels featuring moving own vehicle and moving targets; contains a certification exercise that must be passed.

System Management - two levels of difficulty; difficulty increased by changing the range to the targets presented.

Level 1: Single targets at short range.

Level 2: Single targets at long range.

Table 3

Components of U-COFT Exercise Number 32111

3	2	1	1	1
Matrix: 1=special exercises 2=TC matrix 3=TC/Gunner matrix	System Management Level of Difficulty	Reticle Aim Group	Reticle Aim Difficulty Level within Reticle Aim Group	Target Acquisition Level of Difficulty

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Table 4

U-COFT Matrix Movement Rules

SKILL AREA	MATRIX MOVEMENT RULES		
	TO NEXT HIGHER LEVEL	TO NEXT LOWER LEVEL	TO SKIP A LEVEL
Target Acquisition	Rapid Advance recommendation for last exercise fired, or for two consecutive normal advance recommendations	Two or more consecutive No Advance or Reduction recommendations or a combination of the two recommendations	Not allowed
Reticle Aim	Normal Advance recommendation, except in certain special cases	Not allowed. Reduction in System Management level is recommended	Rapid Advance recommendation. Ir special cases, movement to next level only may be recommended
System Management	Two or more consecutive Normal Advance recommendations together with a Normal or Rapid Advance recommendation for Reticle Aim on the last exercise fired	Exercises that do not contain malfunctions: Two or more consecutive Reduction recommendations for either System Management or Reticle Aim Exercises that contain malfunctions: Two or more consecutive No Advance or Reduction recommendations, or a combination of the those recommendations for either System Management or Reticle Aim	Not allowed

In addition to the exercises recommended by the computer, the I/O may manually select exercises to emphasize certain skill areas. However, exercises selected by the I/O do not affect the crew's progress through the matrix.

Crews making the transition from the M60A3 to the M1 typically receive M1 U-COFT training to supplement on-vehicle and classroom training of tasks. U-COFT transition training, which is self-paced, typically lasts 10 hours, beginning with a one-hour orientation on the M1 U-COFT that includes station preparation and practice firing engagements. All crews start transition training on the U-COFT with an exercise in the TC/gunner matrix that presents a daytime engagement of a stationary target at short range from a stationary vehicle using full-up precision gunnery (Exercise 32111). From there crews progress through the U-COFT matrices following the standard U-COFT progression criteria as applied by the system's computer. After the 10 hours of transition training on U-COFT, crews immediately enter sustainment training. During U-COFT sustainment training, the crews progress through the remainder of the TC and TC/gunner matrices.

U-COFT Research

Studies that have utilized U-COFT can be classified into two categories: (a) those in which performance on U-COFT was used as a predictor of performance on an actual tank, and (b) those in which performance was used a criterion measure. Among the former were studies attempting to use U-COFT performance to predict crew performance in the Canadian Army Trophy (CAT) competition (Black & Abel, 1987) and on Tank Table VIII (Hughes, Butler, Sterling, and Berglund, 1987). Among the latter were studies concerned with the transfer of training between tank gunnery devices (Witmer, 1988a), the effects of degraded gunnery modes on gunner performance (Witmer, 1988b), issues regarding the measurement of U-COFT performance (Du Bois, 1987; Graham, 1986), and the selection of armor crewmen and prediction of combat performance (Black & Graham, 1987; Smith & Graham, 1987; Witmer, 1988b).

In spite of the many studies involving U-COFT, two important issues concerning training on the U-COFT have not yet been fully resolved: (a) the relationship between amount of U-COFT training and gunnery performance, and (b) the development of a standardized measure of performance on U-COFT. Armor officers and NCOs who are responsible for scheduling training on U-COFT lack information on the relationship between the number of hours of U-COFT training and gunnery proficiency. Detailed information regarding this relationship is critical to determining the optimal number of U-COFT training hours and the development of efficient training schedules. Yet, little, if any, information is available on this issue. Each of the studies involving U-COFT, moreover, has used its own measure of performance on U-COFT. Consequently, it is difficult to generalize findings from one study to another. Recognizing the need for a standardized U-COFT performance test, Hoffman and Witmer (1988) developed a test that could be used in future U-COFT research. However, the test has not been implemented in previous U-COFT research, and no information is available concerning the reliability of the measure.

Purpose

The present research, which was designed to track U-COFT skill acquisition via a standardized test over the course of M1 transition training, had three purposes. The primary purpose of this study was to determine the effects amount of U-COFT training (i.e., number of hours on the M1 U-COFT) has on crew gunnery proficiency. The secondary purpose was to determine the effects other training-related variables and soldier-related variables, such as experience and ability, have on crew gunnery proficiency. The final purpose of this research was to assess the reliability of a standard U-COFT test that was designed to evaluate M1 gunnery proficiency of TC-gunner teams.

Method

Participants

Sixty-eight crews participated in the study. The crews, which were from two different battalions, were in the process of transitioning from the M60A3 to the M1 tank.

Procedure

After a one-hour U-COFT familiarization session, all of the crews entered the U-COFT training matrix at the transition level and advanced through the matrix following the standard U-COFT progression criteria. The crews were randomly assigned to one of three groups. The first group was tested after three hours of M1 U-COFT training, the second after six hours, and the third after nine hours. After being tested, the crews continued with their normal U-COFT transition training. It is important to note that the original research plan for this study was to test each crew once during transition training and once during sustainment training. However, the study had to be terminated after the transition training phase due to unavailability of the participating units.

A between-subjects, rather than within-subjects, design was used in this research to control practice effects. The latter experimental design is usually used to study changes in performance due to training or learning (Keppel, 1982). However, a within-subjects design would require each subject to be tested three times during transition training--after three, six and nine hours of training--making it difficult to determine if any improvement in test score was due to the training or to test familiarization. The between-subjects design employed in this study required each subject to be tested only once during transition training, thereby eliminating any practice effects due to test-taking, but retaining the cumulative effects of additional hours of U-COFT training on crew performance.

The M1 U-COFT-Based Crew Gunnery Proficiency Test

The M1 U-COFT-based gunnery proficiency test (UGPT) developed by Hoffman and Witmer (1988) was used to assess U-COFT gunnery proficiency. A detailed description of this test is provided by those authors. A brief description of the procedures used in this study with respect to the UGPT is provided below.

One hour was allotted for testing. This allotted hour immediately followed the crew's third, sixth, or ninth hour of transition training on U-COFT. Due to the one-hour time constraint, the UGPT was limited to four U-COFT exercises. The exercises were selected on the basis of their coverage of the gunnery domain. The domain was specified in terms of the conditions that define the tasks included in Tank Table VIII as described in Tank Combat Tables M1 (FM-17-12-1, 1986). Tank Table VIII is the final crew exercise in a series of tank exercises and is used to qualify individual tank crews.

Four exercises from reticle aim groups 5 and 6 of the TC/gunner matrix were chosen for the test. Each exercise included from four to ten engagements. The engagement conditions for each of the exercises are shown in Appendix B. Three exercises (34633, 34611, and 34622) were selected from reticle aim group 6, and one (31563) from reticle aim group 5. Two engagements in exercises 34611 and 34622 were modified to increase their correspondence with the exercises comprising Table VIII. One engagement from each exercise was changed to an NBC engagement by requiring the crews to don protective masks. In the other engagement, the TC was required to fire the main gun without the gunner's assistance in order to simulate a 3-man crew.

Transition training on the U-COFT is usually conducted by the New Equipment Training Team (NET-T). To assure standardized administration procedures, however, two non-military I/Os were used to administer the UGPT. The I/Os received instruction from the researchers detailing how to administer the test without providing feedback, the importance of not altering the directions read to each crew, and the difference between testing and training. They were also required to run through several practice administrations prior to the start of testing.

Soldier-Based Predictor Variables

Data on soldier-based predictor variables were collected by having the test administrator complete the Biographical Questionnaire presented in Appendix C for each soldier who participated in the research. The following variables from the questionnaire were included in the analyses as measures of experience: time in armor, time in position, and time with partner. Scores on the ASVAB composite scales were also obtained from each soldier's personnel (201) file. Scores from the Combat (CO) and General Technical (GT) scales were chosen as measures of ability. The CO scale, which is used to select armor recruits, is a composite of four ASVAB components: arithmetic reasoning, coding speed, auto shop information, and mechanical comprehension. GT scores, which are composed of verbal and arithmetic reasoning components, are considered to be roughly equivalent to intelligence test scores. GT score is one of the criteria used to select soldiers for Officers Candidate School.

Training-Based Predictor Variables

Data were collected reflecting the amount of transition training each crew had received prior to taking the UGPT. Information regarding the number of hours spent during transition training in the classroom and on the M1 tank was extracted from the Biographical Questionnaire. The amount of time each

gunner and TC had spent on the M60A3 and M1 U-COFT systems prior to the administration of the UGPT, as reported on the Biographical Questionnaire, was also used.

In addition to the data that were collected on time spent in transition training, U-COFT printouts were used to collect information reflecting the U-COFT performance of each crew at the time the crew was tested. This information consisted of (a) the total number of exercises (i.e., exercises selected by the I/O as well as exercises chosen by the computer) completed in each of the two matrices, and (b) the reticle aim difficulty level that had been attained in each training matrix. Reticle aim difficulty level is generally regarded as the best indicator of a crew's progress within a matrix even though Hughes et al. (1987) suggest that it is not a perfect indicator of the difficulty of an exercise. Information regarding the two performance measures cited above was also collected for each crew after nine hours of transition training on the M1 U-COFT. This information was interpreted as an indicator of the rate at which crews progressed through each matrix during transition training.

Criterion Performance Measures

Criterion tests of overall job performance usually produce a single score. In most cases, test items or tasks are scored separately and combined in some manner to arrive at an aggregate score. The various scales used to measure tank gunnery performance (e.g., opening time, time to first hit, total time, number of hits, number of procedural errors, hit probability), however, cannot be easily summed or averaged to yield a meaningful composite score (Hoffman & Witmer, 1988). Consequently, the UGPT generates several criterion measures of gunnery proficiency. These measures are described below.

Determining a composite score for a U-COFT-based test is further constrained by the kinds of information provided by U-COFT printouts. The printouts contain information regarding the engagements for each exercise fired. However, since the UGPT was designed to measure overall gunnery proficiency, scores on the individual engagements or exercises are not as meaningful as composite scores across engagements and exercises. Therefore, data provided by U-COFT printouts were used to determine scores for each engagement; these scores were then used to calculate performance measures across exercises and engagements.

Overall hit rate (a composite of time, rounds, and hits) was chosen as the primary dependent variable. Since it incorporates measures of both speed and accuracy, overall hit rate best reflects a crew's overall gunnery proficiency. Six secondary criterion measures were also calculated from the U-COFT data: overall firing rate, overall hit proportion, average miss distance, average opening time, average number of target acquisition errors, and average number of system management errors. The procedures for scoring the individual engagements and calculating the scores across engagements are presented in Appendix D.

Analyses

The predictor and criterion measures that were included in the analyses are presented in Table 5. The data analyses were conducted in four phases as follows:

1. Analysis of variance (ANOVA) procedures were conducted to compare the three groups (i.e., the groups that were tested after 3-, 6-, or 9-hours of transition training on the M1 U-COFT) in terms of the soldier-based predictor measures, the training-based predictor measures, and the criterion measures.

2. Correlations were computed between the predictor variables (i.e., the soldier-based and training-based variables) and the criterion performance measures.

3. Intercorrelations were computed within each of the two sets of predictor variables and within the set of criterion measures.

4. The reliability of the UGPT was assessed by calculating Spearman-Brown correlation coefficients in order to determine the test's internal consistency.

Table 5

Variables Included in the Data Analyses

Predictor Measures		Criterion Measures
Soldier-Based	Training-Based	U-COFT Performance
Time in Armor	Classroom Hours	Overall Hit Rate
Time in Position	Vehicle Hours	Overall Fire Rate
Time with Partner	A3 U-COFT Hours	Overall Hit Proportion
ASVAB CO Score	M1 U-COFT Hours	Average Opening Time
ASVAB GT Score	Total Exercises - TC Matrix	Average Miss Distance
	Total Exercises - TC/Gunner Matrix	Average Target Acquisition Errors
	Reticle Aim Difficulty Level - TC Matrix	Average System Management Errors
	Reticle Aim Difficulty Level - TC/Gunner Matrix	

Results and Discussion

The results of the analyses are reported by phase in the following sections.

Comparisons Among the 3-, 6-, and 9-Hour Groups

Soldier-based predictor variables. The data extracted from the biographical questionnaires, which are summarized in Appendix E, show that the three groups were quite homogeneous. This observation is supported by a series of ANOVAs that failed to reveal any differences among the 3-, 6-, and 9-hour groups on any of the soldier-based predictor measures.

Training-based predictor measures[2]. The groups differed with regard to all of the training-based predictor variables except number of hours on the M60A3 U-COFT and number of hours of transition classroom training. Differences were found in (a) the number of hours of M1 U-COFT training reported by the gunners ($F(2,65) = 3.99$, $p < .05$); (b) the number of hours spent on the M1 tank by TCs ($F(2,61) = 5.60$, $p < .01$) and gunners ($F(2,62) = 4.08$, $p < .05$); (c) the number of U-COFT exercises completed in the TC/gunner matrix ($F(2,50) = 40.75$, $p < .001$) and the TC matrix ($F(2,50) = 37.76$, $p < .001$); and (d) reticle aim difficulty level in the TC/gunner matrix ($F(2,56) = 16.46$, $p < .001$) and the TC matrix ($F(2,56) = 18.23$, $p < .001$). Descriptive statistics for the training-based U-COFT predictor measures are shown in Table 6. These findings were expected, of course, since the more time the crews had spent in transition training, the more training they would have received both on the M1 tank and the M1 U-COFT.

Post hoc comparisons showed that (a) gunners in the 6- and 9-hour groups reported significantly more hours on the M1 U-COFT than did those in the 3-hour group ($F(2,65) = 7.95$, $p < .01$); (b) the TCs and gunners in the 9-hour group reported spending more time on the vehicle than their counterparts in the 3- and 6-hour groups ($F(1,61) = 10.70$, $p < .01$ and $F(1,62) = 7.65$, $p < .01$); (c) more exercises were completed in the TC and TC/gunner matrices by the 9-hour group than the 6-hour group ($F(1,50) = 24.80$, $p > .001$ and $F(1,50) = 31.89$, $p > .001$), and by the 6-hour group than the 3-hour group ($F(1,50) = 10.30$, $p > .01$ and $F(1,50) = 12.63$, $p > .001$); and (d) a higher reticle aim difficulty level was attained in the TC and TC/gunner matrices by the 9-hour group than the 6-hour group ($F(1,56) = 10.68$, $p > .01$ and $F(1,56) = 6.89$, $p > .05$), and by the 6-hour group than the 3-hour group ($F(1,56) = 5.94$, $p > .05$ and $F(1,56) = 8.56$, $p > .01$). Figures 1 through 4 present the number of exercises completed and reticle aim difficulty level attained by group for the TC and TC/gunner matrices.

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[2]The U-COFT training printouts were incomplete for some of the crews in the study. As a result, for the training-based U-COFT predictor variables, the number of crews reported may be less than the total number of crews in that group.

Table 6

Summary Statistics for Training-Based U-COFT Predictor Variables

Variable	Tested After 3-Hours	6-Hours	9-Hours
TC Matrix			
Total number of exercises completed:			
n	23	15	15
Minimum	0.00	0.00	5.00
Maximum	7.00	11.00	14.00
Mean	1.48	4.13	8.67
S.D.	2.09	2.90	2.64
Reticle Aim Difficulty level:			
n	23	17	19
Minimum	0.00	0.00	1.00
Maximum	1.00	5.00	9.00
Mean	0.61	2.00	3.95
S.D.	0.50	1.49	2.78
TC/Gunner Matrix			
Total number of exercises completed:			
n	23	15	15
Minimum	3.00	7.00	12.00
Maximum	17.00	22.00	26.00
Mean	7.74	11.93	19.27
S.D.	3.28	4.13	3.35
Reticle Aim Difficulty level:			
n	22	18	19
Minimum	1.00	3.00	3.00
Maximum	6.00	14.00	33.00
Mean	3.32	7.06	10.53
S.D.	1.39	3.02	6.27

Note. For each of the variables presented, 9-hour group mean > 6-hour group mean > 3-hour group mean, $p < .001$.

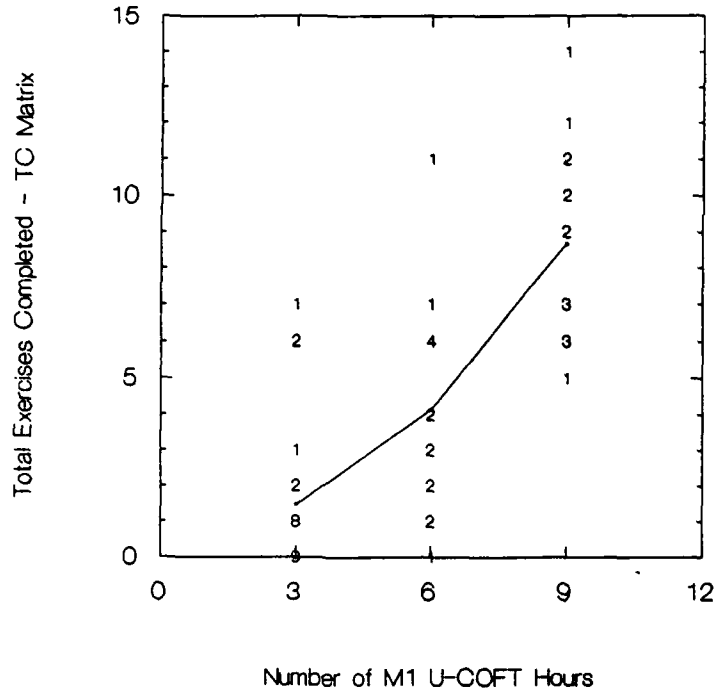

Figure 1. Total number of TC matrix exercises completed by crews tested after 3-, 6-, and 9-hours of transition training on the M1 U-COFT, with a plot of group means.

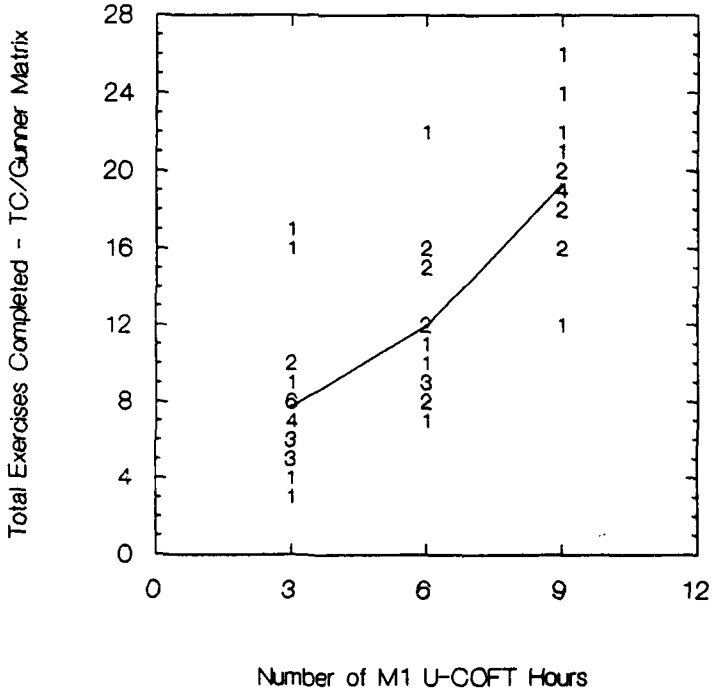

Figure 2. Total number of TC/Gunner matrix exercises completed by crews tested after 3-, 6-, and 9-hours of transition training on the M1 U-COFT, with a plot of group means.

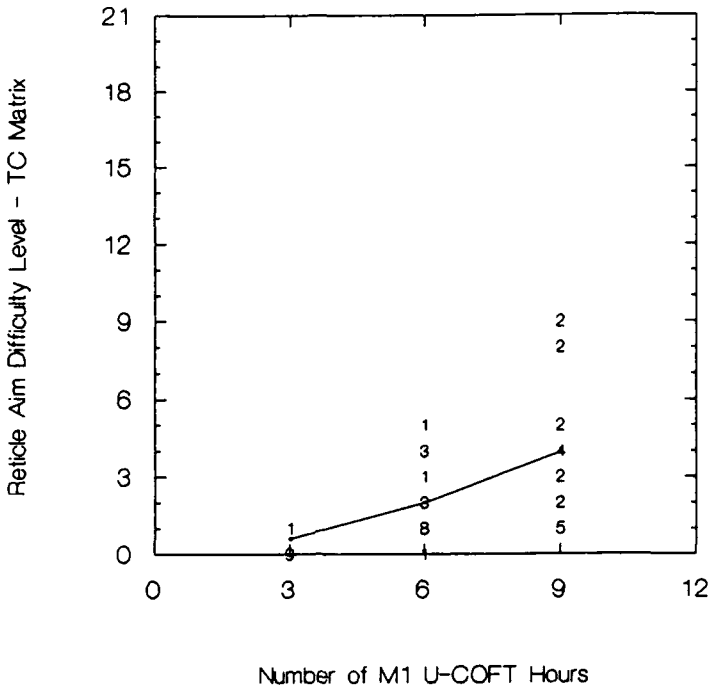

Figure 3. Reticle aim difficulty level attained in the TC matrix by crews tested after 3-, 6-, and 9-hours of transition training on the M1 U-COFT, with a plot of group means.

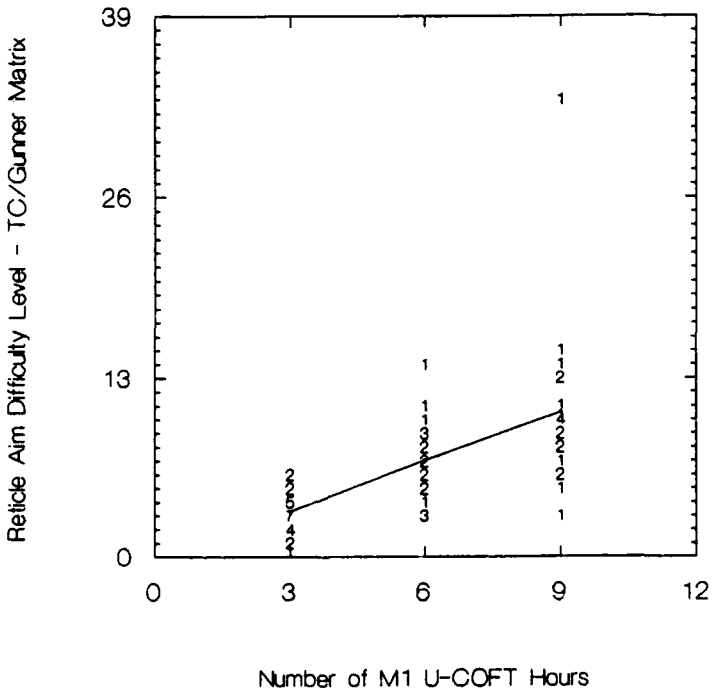

Figure 4. Reticle aim difficulty level attained in the TC/Gunner matrix by crews tested after 3-, 6-, and 9-hours of transition training on the M1 U-COFT, with a plot of group means.

The number of exercises completed and reticle aim difficulty level attained by each group at the end of the 9-hour transition training period were also compared for both the TC and TC/gunner matrices. As shown in Table 7, the three groups did not differ significantly with regard to the total number of exercises completed or reticle aim difficulty level attained in either matrix. This indicates that over the course of the 9-hour period of transition training on the U-COFT, none of the groups received substantially more practice firing exercises than the other groups, and none of the groups progressed significantly farther in the matrices than the other groups.

Table 7

Group Means on Training-Based U-COFT Predictor Variables After Nine Hours of Transition Training

Variable	Tested After 3-Hours	6-Hours	9-Hours
TC Matrix:			
Total number of exercises completed	8.05	7.80	8.67
Reticle Aim Difficulty level	5.04	3.78	4.15
TC/Gunner Matrix:			
Total number of exercises completed	20.85	18.67	19.27
Reticle Aim Difficulty level	10.71	9.74	10.50

Criterion measures. Table 8 presents summary statistics, by group, for each criterion measure. Significant main effects were obtained for two of the measures: average miss distance ($F(2,65) = 3.50$, $p < .05$) and system management errors ($F(2,65) = 3.14$, $p < .05$). Post hoc comparisons of the data revealed that the 6- and 9-hour groups aimed more accurately at targets than the 3-hour group ($F(1,65) = 6.584$, $p < .05$), but that the 9-hour group made significantly more system management errors than the 3- or 6-hour groups ($F(1,65) = 5.609$, $p < .05$). Although the 9-hour group made more system management errors than the other two groups, these errors were infrequent since the 9-hour group averaged only 0.25 errors per test.

Since significant main effects in the expected direction were obtained for only one of the seven criterion measures (average miss distance), the results appear to offer little support for the notion that learning takes place during the first nine hours of transition training on the M1 U-COFT. Some indication that learning did actually take place is provided, however, by the fact that within-group variance decreased over time for two of the criterion measures: average miss distance and average opening time. Earlier

Table 8

Summary Statistics for the Criterion Measures

Criterion Variable	Tested After 3-Hours (n=26)	6-Hours (n=22)	9-Hours (n=20)
Overall Hit Rate:			
Minimum	0.359	0.810	0.824
Maximum	3.135	2.695	3.438
Mean	1.638	1.722	1.847
S.D.	0.681	0.528	0.675
Overall Fire Rate:			
Minimum	1.617	2.211	2.511
Maximum	5.163	5.365	5.782
Mean	3.145	3.355	3.533
S.D.	0.766	0.732	0.837
Overall Hit Proportion:			
Minimum	0.222	0.349	0.292
Maximum	0.828	0.789	0.697
Mean	0.509	0.511	0.514
S.D.	0.156	0.108	0.112
Average Miss Distance:[a]			
Minimum	0.819	0.877	0.778
Maximum	4.383	2.893	1.799
Mean	1.661	1.303	1.153
S.D.	0.978	0.467	0.249
Average Opening Time:			
Minimum	13.910	13.840	12.450
Maximum	26.880	23.740	23.300
Mean	19.332	18.403	17.213
S.D.	3.272	3.083	2.730
Average Target Acquisition Errors:			
Minimum	0.773	0.905	0.750
Maximum	2.238	2.300	2.318
Mean	1.592	1.531	1.416
S.D.	0.357	0.386	0.397
Average System Management Errors:[b]			
Minimum	0.000	0.000	0.048
Maximum	0.400	0.550	0.952
Mean	0.134	0.166	0.245
S.D.	0.108	0.132	0.209

[a] 6- and 9-hour means < 3-hour mean, $p < .05$. [b] 9-hour group mean > 3- and 6-hour group means, $p < .05$.

research findings by Witmer (1988a) also suggest that learning may have occurred. According to Witmer, average miss distance is more sensitive than the other measures of gunnery proficiency since it assesses improvements in performance even when crews lack the skills needed to hit the target. If Witmer's contention is correct, then the superior performance of the 6- and 9-hour groups on just that one measure may have been due to the possibility that average miss distance was the only measure sensitive enough to detect differences between groups after only nine hours of training. Improvements on the other measures would be expected after additional training on U-COFT, but the early termination of data collection made it impossible to determine whether or not these expected improvements would have taken place.

There are three other explanations, besides test sensitivity, for the failure to obtain significant mean group differences on five of the seven criterion measures (i.e., overall hit rate, overall firing rate, overall hit proportion, average opening time, and average target acquisition errors). One possible explanation is that the groups differed in the amount of U-COFT training they received prior to transition training. This prior U-COFT experience could have concealed effects due to U-COFT transition training. A second explanation is the possibility that the UGPT may not have been a representative test of the skills learned on the U-COFT during the nine hours of transition training. The third explanation is the possibility that learning did not take place during the nine hours of transition training on the M1 U-COFT.

To control for prior U-COFT training, the data were reanalyzed using analysis of covariance (ANCOVA). Prior U-COFT experience was calculated by subtracting the number of hours spent on the M1 U-COFT during transition training from the total number of U-COFT training hours (i.e., hours on M60A3 U-COFT plus hours on M1 U-COFT) reported by each soldier on the biographical questionnaire. The resulting number of hours obtained for the gunners correlated with overall hit rate ($\underline{r}$ = .30), overall hit proportion ($\underline{r}$ = .26), and average target acquisition errors ($\underline{r}$ = -.27), supporting the notion that prior U-COFT experience affected the performance of gunners. However, the resulting number of hours obtained for the TCs did not correlate with any of the criterion measures. Since one prerequisite for a covariate is a significant correlation with the dependent variable (Keppel, 1982), the ANCOVAs were performed using gunners prior U-COFT experience as the covariate. The results failed to reveal any effects of hours of U-COFT transition training on U-COFT gunnery proficiency even when the effects of earlier U-COFT training were statistically controlled. Thus, the failure to obtain group differences on five of the seven criterion measures does not appear to be caused by prior training on U-COFT.

The premise that the UGPT was not representative of the skills learned during first nine hours of U-COFT training was supported by the lack of progress made by crews in both training matrices. As shown in Figures 3 and 4, only two crews had reached or exceeded reticle aim difficulty level 15 of the TC/gunner matrix (i.e., progressed into reticle aim group 3), and none had reached reticle aim difficulty level 11 in the TC matrix (i.e., progressed into reticle aim group 3). As a consequence, the majority of the crews only practiced engaging stationary targets from stationary vehicles. Since only

four of the 23 UGPT engagements involved firing under those conditions, the gunnery proficiency scores could have reflected skills that were not trained during the study.

Since the UGPT contained both stationary and moving engagements, the effects of M1 U-COFT training on each type of engagement could be assessed using multivariate analysis of variance (MANOVA). For this reason, a MANOVA was conducted using number of hours of U-COFT transition training as the between-subjects factor and firing tank (stationary or moving) and target (stationary or moving) as within-subjects factors. The results of the MANOVA, which are presented in Appendix F, indicated that there were no significant interactions between hours of U-COFT transition training and the type of gunnery engagement that was conducted on the criterion test. This finding suggests that the failure to find significant differences among the three groups (i.e., groups with 3-, 6-, or 9-hours of training on the M1 U-COFT) was not due to the predominance of moving engagements on the criterion test.

The reason why crews in the 9-hour group made significantly more system management errors than the crews in the 3- and 6-hour groups is difficult to explain. The increase in the within-group variances for system management errors over time suggests that some of the crews were beginning to make inappropriate responses unique to the simulator. For example, crews may have stopped lasing to the targets since failing to lase would have no effect on target hits. However, whenever a crew failed to lase, the crew was scored as having made a system management error.

Correlations Between Predictor and Criterion Measures[3]

Correlations between soldier-based predictor variables and criterion measures. Table 9 presents correlations between the soldier- and training-based predictor variables and the criterion measures. Contrary to expectations, the amount of time TCs and gunners had been paired was positively correlated with average miss distance (r = .35 and r = .31, respectively) and average opening time (r = .35 and r = .29, respectively). That is, the longer the crews had been paired together, the slower their opening time and the less accurate their aim. Also contrary to expectations were the significant relationships between TC time in position and overall hit rate (r = -.25), overall fire rate (r = -.28), and target acquisition errors (r = .37). These findings indicate that inexperienced TCs fired quicker and were more accurate at identifying and classifying the targets presented. Gunner's CO score was related positively to overall hit proportion (r = .27) and negatively to target acquisition errors (r = -.25). That is, the gunners with higher CO scores tended to fire with more accuracy and to make fewer target acquisition errors. This finding suggests that CO score may tap some

[3]The Biographical Questionnaires were completed by the test administrators based on information reported by the soldiers. Differences in the correlations between TCs and gunners for the following variables--time with partner, classroom hours, vehicle hours--are largely due to differences in the data reported by the soldiers.

Table 9

Correlations Between Soldier- and Training-Based Predictor Measures and Criterion Measures

Predictor Variables	n	Criterion Measures: Overall Hit Rate	Overall Fire Rate	Overall Hit Prop.	Average Opening Time	Average Miss Distance	Average Target Acquis. Errors	Average System Management Errors
Soldier-Based								
TC Time in Armor	68	-.15	-.08	-.11	.10	.17	.05	.04
TC Time in Position	68	-.25*	-.28**	-.10	.19	.16	.37**	.08
TC Time with Partner	68	-.14	-.15	-.03	.35**	.35**	.16	-.04
TC ASVAB CO Score	65	-.09	-.01	-.14	-.02	-.01	.05	.21
TC ASVAB GT Score	66	-.11	.00	-.17	.10	.10	.07	.02
GNR Time in Armor	68	.06	.02	.09	-.02	-.01	-.08	.13
GNR Time in Position	68	-.03	-.14	.10	.10	-.09	.15	-.03
GNR Time with Partner	68	-.06	-.13	.06	.29*	.31*	.13	-.05
GNR ASVAB CO Score	66	.22	.06	.27*	-.17	-.23	-.25*	-.09
GNR ASVAB GT Score	66	-.04	-.04	-.11	.03	-.04	-.07	.14
Training-Based								
TC M60A3 U-COFT Hours	64	.05	.01	.01	-.07	.04	.19	-.13
TC M1 U-COFT Hours	68	-.11	-.08	-.12	.21	.05	.15	.23
TC Classroom Hours	64	-.11	.16	.03	-.20	-.10	-.32**	-.09
TC Vehicle Hours	64	-.06	-.04	-.01	-.01	-.18	.06	-.04
GNR M60A3 U-COFT Hours	64	.28*	.16	.26*	-.05	-.17	-.23	-.04
GNR M1 U-COFT Hours	68	.06	.09	.10	-.13	-.15	-.22	.32
GNR Classroom Hours	64	.15	.21	.03	-.25*	-.10	-.28*	-.04
GNR Vehicle Hours	64	-.01	.01	.02	-.10	-.21	.03	.01
Tot. Exercises TC Matrix	53	.41**	.36**	.31*	-.39**	-.43**	-.46**	.08
Reticle Aim TC Matrix	59	.24	.17	.23	-.22	-.29*	-.29*	.09
Tot. Exercises TC/GNR Matrix	53	.29*	.32*	.16	-.34*	-.32*	-.30*	.19
Reticle Aim TC/GNR Matrix	59	.27*	.23	.23	-.32**	-.35**	-.27*	.23

*$p < .05$. **$p < .01$.

general aptitude necessary for successful performance as an armor gunner. In general, the effects of the soldier-based variables on UGPT performance are not clear and are difficult to interpret.

Correlations between training-based predictor variables and criterion measures. Hours on the M1 U-COFT was unrelated to any of the criterion variables for both gunners and TCs. The possible reasons for failing to obtain significant correlations between the number of hours of M1 U-COFT training and gunnery performance are the same as the possible reasons for the failure to find significant main effect for groups for most of the performance measures: there may be no relationship, prior training on the M60A3 U-COFT may have masked the relationship, or the criterion test may have been an inadequate measure of the skills learned during the nine hours of U-COFT transition training. The results of the ANCOVA failed to support the masking effect of prior U-COFT experience, and the MANOVA failed to support the possible discrepancy between the skills trained during transition training on U-COFT and those measured by the criterion test.

There is an additional explanation, however, that may account for the failure to obtain significant correlations between hours of M1 U-COFT training and the criterion variables. This explanation concerns the shape of the learning curve and the location of soldiers along this curve. Learning curves are seldom as smooth as the hypothetical S-shaped learning curve shown in Figure 5. Most learning curves have plateaus as shown in Figure 6 (Bass & Vaughan, 1966).

The correlation between hours of M1 U-COFT training and gunnery performance would depend on the location of the soldiers along the curve at the start of training and when performance is measured (on the learning curve in Figure 6, onset of training is represented by t1 and measurement of performance by t2). Performance data collected on soldiers that are at the lower level on the curve (Point A along the learning curve in Figure 6) should yield a positive correlation between hours of training on the M1 U-COFT and skill level. Similarly, data collected on soldiers at the upper level of the curve (Point C along the learning curve in Figure 6) should also yield a positive correlation between the two sets of variables. However, data collected in the middle of the curve (Point B along the learning curve in Figure 6) should fail to yield a significant correlation since little learning would actually have taken place. Since most of the soldiers had experience on the M60A3 U-COFT, they were probably somewhere along the middle part of the M1 U-COFT learning curve. Consequently, the correlations between hours of M1 U-COFT training and the criterion measures should not have been significant.

Number of hours on the M60A3 U-COFT did not correlate significantly with any of the criterion measures for TCs. It was significantly related to overall hit rate (r = .28) and overall hit proportion (r = .26) for gunners, however. The significant correlations between time spent on the M60A3 U-COFT and the two performance criteria related to target hits (i.e., overall hit rate and overall hit proportion), combined with the lack of a significant correlation between time spent on the M60A3 U-COFT and overall firing rate, suggest that prestudy experience on that U-COFT system had an effect on the

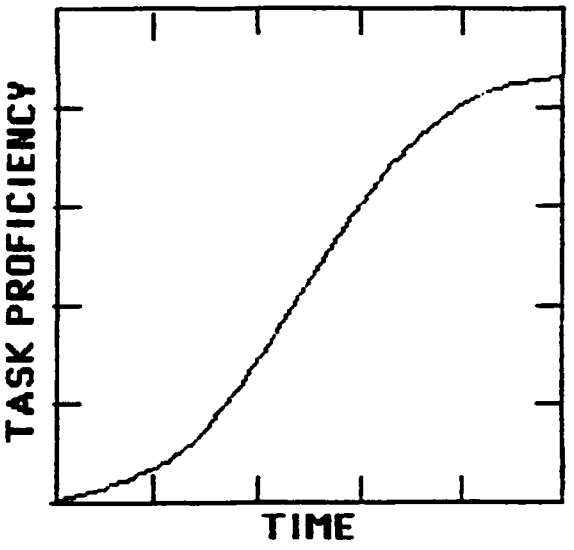

Figure 5. Hypothetical S-shaped learning curve.

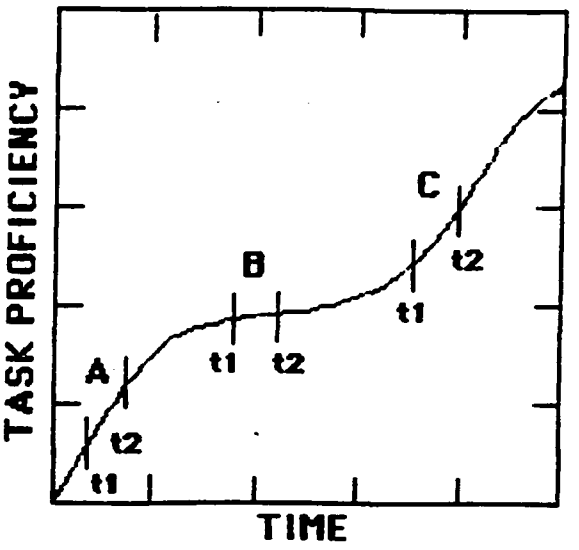

Figure 6. Learning curve with a plateau.

accuracy with which crews hit targets, but not the speed with which those hits were made. The differential effects on accuracy and speed may be explained on the basis of the similarities and differences between the fire control systems on the M60A3 and M1 tanks (and thus on the similarities and differences between the simulated fire control systems on their corresponding U-COFTs). Many of the required actions on the M60A3 and M1 systems are virtually the same, but some are quite different. Among the actions that are essentially the same on both systems are the identification of targets and the operation of the control handles. Given these similarities, crews experienced on the M60A3 should be able to lay and fire with greater accuracy at the onset of M1 U-COFT training. On the other hand, the dissimilarities between the two systems (e.g., the placement of the fire system control switches) may interfere with the speed with which these crews can complete the engagements.

Among the training-based predictor variables related to U-COFT, the total number of exercises completed in the TC and TC/gunner matrices correlated significantly with overall hit rate ($\underline{r}$ = .41 and $\underline{r}$ = .29), overall fire rate ($\underline{r}$ = .36 and $\underline{r}$ = .32), average opening time ($\underline{r}$ = -.39 and $\underline{r}$ = -.34), average miss distance ($\underline{r}$ = -.43 and $\underline{r}$ = -.32), and average target acquisition errors ($\underline{r}$ = -.46 and $\underline{r}$ = -.30). In addition, the number of exercises completed in the TC matrix was significantly related to overall hit proportion ($\underline{r}$ = .31). Thus, the greater number of exercises that were completed, the better the performance. Although correlations do not establish cause and effect, these significant relationships were probably obtained because the better the TCs and gunners were able to complete more of the exercises. That is, the soldiers who were able to complete the most exercises were apt to be

those that made the fewest errors in target acquisition, those who were able to shoot the fastest, and those who were able to aim with the greatest accuracy.

Reticle aim difficulty level attained in the TC and TC/gunner matrices, respectively, correlated significantly with average miss distance ($\underline{r}$ = -.29 and $\underline{r}$ = -.35) and average target acquisition errors ($\underline{r}$ = -.29 and $\underline{r}$ = -.27). Reticle aim level in the TC/gunner matrix was also significantly correlated with overall hit rate ($\underline{r}$ = .27) and average opening time ($\underline{r}$ = -.32). Once again, although correlations do not establish cause and effect, it is likely that the better gunners and TCs progressed farther in each matrix. In other words, TCs and gunners who attained the highest reticle aim levels probably aimed more accurately, made fewer target acquisition errors, and had faster opening times than those who attained lower reticle aim levels.

For both TCs and gunners, the number of hours in the classroom was negatively related to target acquisition errors ($\underline{r}$ = -.32 and $\underline{r}$ = -.28, respectively), while gunners classroom time was also negatively related to average opening time ($\underline{r}$ = -.25). These results indicate that crews who had more transition training in the classroom tended to have faster opening times and to make fewer mistakes in acquiring targets. This suggests that classroom transition training may facilitate knowledge of where the M1 controls are located. This knowledge, in turn, would reduce engagement time. However, this proposition is not supported by the relationship between opening time and M1 vehicle hours since the correlation between those two variables was not significant. The relationship between transition time in the classroom and target acquisition errors is even harder to explain. This difficulty is due to the fact that time in class is devoted to familiarizing crewmen with the switches, controls, and displays of the M1 tank--not to threat recognition and classification.

Intercorrelations Among Predictor Measures and Criterion Measures

Table 10 presents intercorrelations among the U-COFT performance criterion measures. All of the correlations among the criterion measures were significant except for those involving system management errors. That system management errors was not significantly correlated with any of the other criterion measures is not too surprising given that few system management errors were made at all. Intercorrelations among the soldier- and training-based predictor measures are shown in Table 11. All of the training-based U-COFT measures were highly intercorrelated.

Test Reliability

The reliability of each measure was assessed by first computing intercorrelations for that measure across 22 engagements[4]. The intercorrelations were then transformed into Fisher's $\underline{z}$ coefficients. The

[4]UGPT engagement 18 was excluded because it does not contain any threat vehicles; the only performance measure scored is whether or not the friendly tank was hit.

average Fisher's z was calculated next and then transformed back into a correlation coefficient (Silver & Dunlap, 1987). The resulting correlation was then adjusted using the Spearman-Brown formula, the length of the test being equal to the average number of engagements fired. The average number of engagements fired for all criterion measures was 21 (crews averaged one missing engagement). The reliability coefficients and mean test score across engagements for the criterion measures are shown in Table 12. The reliability coefficients, which ranged from .51 to .77 for the various performance criteria, are generally consistent with the test-retest reliabilities previously reported by Graham (1986), Du Bois (1987), and Witmer (1988a).

As in past U-COFT tests, opening time was found to be the most reliable measure. Average miss distance had a much higher reliability for the current test than on previous tests, although the higher reliability may be the result of method used to calculate reliability. The previous studies used test-retest measures of reliability. These measures may be influenced by differential improvement in test scores across subjects from the first to the second testing session reducing reliability estimates for those variables that are sensitive to learning effects. The method used to calculate reliability in the current study is less likely to be influenced by the learning that may occur during testing. Another factor that may account for the increased stability of average miss distance in this study is the amount of time crews trained together. Crews in the present study trained together on the U-COFT for a minimum of three hours. In the earlier studies, a confederate of the researcher was used as TC. As a consequence, crews had little time to develop the coordination or continuity of actions necessary to perform such a complex crew task quickly and consistently.

Table 10

Intercorrelations Among Criterion Measures

	1	2	3	4	5	6	7
(n=68)							
1. Overall Hit Rate	1.00						
2. Overall Fire Rate	.79**	1.00					
3. Overall Hit Proportion	.79**	.27*	1.00				
4. Average Opening Time	-.75**	-.84**	-.37**	1.00			
5. Average Miss Distance	-.56**	-.34**	-.57**	.41**	1.00		
6. Average Target Acquisition Errors	-.80**	-.77**	-.51**	.78**	.45**	1.00	
7. Average System Management Errors	.04	.23	-.19	-.21	.08	-.09	1.00

*p < .05. **p < .01.

Table 11

Intercorrelations Among Soldier- and Training-Based Predictor Measures

	1	2	3	4	5	6	7	8	9	10
Soldier-Based										
1. TC Time in Armor	1.00									
n	68									
2. TC Time in Position	.21	1.00								
n	68	68								
3. TC Time with Partner	.12	.13	1.00							
n	68	68	68							
4. TC ASVAB CO Score	-.30*	.12	.08	1.00						
n	65	65	65	65						
5. TC ASVAB GT Score	-.13	.03	.13	.51**	1.00					
n	66	66	66	65	65					
6. GNR Time in Armor	.12	.08	-.07	-.11	.03	1.00				
n	68	68	68	65	66	68				
7. GNR Time in Position	-.15	.04	.07	.07	.15	.35**	1.00			
n	68	68	68	65	66	68	68			
8. GNR Time with Partner	.10	.25*	.91**	.04	.07	-.07	.09	1.00		
n	68	68	68	65	66	68	68	68		
9. GNR ASVAB CO Score	-.07	.01	.05	.11	-.01	-.33**	-.33**	.06	1.00	
n	66	66	66	64	65	66	66	66	66	
1. GNR ASVAB GT Score	.01	-.08	-.04	.18	.15	-.22	-.25	-.04	.72**	1.00
n	66	66	66	64	65	66	66	66	66	66
Training-Based										
11. TC M60A3 U-COFT Hours	.07	.08	.16	.05	-.24	-.17	-.13	.19	.12	.15
n	64	64	64	61	62	64	64	64	63	63
12. TC M1 U-COFT Hours	-.04	.05	-.01	-.13	.08	.21	-.05	-.02	-.14	.22
n	68	68	68	65	66	68	68	68	66	66
13. TC Classroom Hours	-.16	-.29*	-.19	-.07	-.14	.01	-.38**	-.17	.14	.14
n	64	64	64	65	62	64	64	64	62	62
14. TC Tank Hours	.11	.08	-.11	.00	-.22	.03	.02	-.15	.01	.05
n	64	64	64	61	62	64	64	64	62	62
15. GNR M60A3 U-COFT Hours	.22	.02	-.12	-.03	.06	.11	-.08	-.17	.11	.14
n	64	64	64	61	62	64	64	64	62	62
16. GNR M1 U-COFT Hours	.14	-.07	-.12	-.32**	-.15	-.02	-.05	-.02	-.10	-.06
n	68	65	68	65	66	68	68	68	66	66
17. GNR Classroom Hours	-.13	-.24	-.15	-.05	-.15	.10	-.34**	-.17	.08	.06
n	65	65	65	62	63	65	65	65	63	63
18. GNR Tank Hours	-.05	.02	-.07	.08	-.13	.00	.09	-.10	.03	.05
n	65	65	65	62	63	63	65	65	63	63
19. Tot Exercises TC Matrix	-.01	-.01	-.12	-.17	-.16	.32*	.17	-.02	.03	-.03
n	53	53	53	51	52	53	53	53	51	51
2. Reticle Aim TC Matrix	-.02	.03	.02	-.08	-.20	.34**	.18	.14	.02	-.10
n	59	59	59	57	58	59	59	59	57	57
21. Tot Exercises TC/GNR Matrix	.03	.01	.05	-.04	-.01	.28*	.25	.11	-.09	-.15
n	53	53	53	51	52	53	53	53	51	51
22. Reticle Aim TC/GNR Matrix	.74	.09	-.07	-.05	-.15	.20	.11	-.03	.15	.07
n	59	59	59	57	58	59	59	59	57	57

*$p < .05$. **$p < .01$.

(table continues)

Table 11 (continued)

Intercorrelations Among Soldier- and Training-Based Predictor Measures

	11	12	13	14	15	16	17	18	19	20	21	22
Training-Based												
11. TC M60A3 U-COFT Hours	1.00											
n	64											
12. TC M1 U-COFT Hours	-.08	1.00										
n	64	68										
13. TC Classroom Hours	.06	.09	1.00									
n	60	64	64									
14. TC Tank Hours	.25*	-.10	-.00	1.00								
n	60	64	61	64								
15. GNR M60A3 U-COFT Hours	.09	.15	.01	.12	1.00							
n	60	64	60	61	64							
16. GNR M1 U-COFT Hours	-.20	-.10	.06	-.05	-.18	1.00						
n	64	68	64	64	64	68						
17. GNR Classroom Hours	.06	.13	.89**	.06	.06	-.03	1.00					
n	61	65	63	61	61	65	65					
18. GNR Tank Hours	.27*	-.13	.01	.88**	-.03	-.03	.10	1.00				
n	61	65	61	63	61	65	62	65				
19. Tot Exercises TC Matrix	-.13	-.27	.08	.27	.12	.30*	.11	.17	1.00			
n	50	53	50	49	51	53	50	50	53			
2. Reticle Aim TC Matrix	-.09	-.20	.05	.26	.01	.27*	.05	.23	.85**	1.00		
n	56	59	56	55	57	59	56	56	52	59		
21. Tot Exercises TC/GNR Matrix	-.14	-.29*	-.02	.24	-.05	.23	.03	.21	.87**	.75**	1.00	
n	50	53	50	49	51	53	50	50	53	52	53	
22. Reticle Aim TC/GNR Matrix	-.08	-.19	-.02	.20	.16	.20	.01	.12	.73**	.70**	.69**	1.00
n	56	59	56	55	57	59	56	56	52	58	52	59

*$p < .05$. **$p < .01$.

Table 12

Mean Test Scores and Reliability Coefficients for Performance Criterion Measures

Criterion Measure	Score Range	Test Mean	Adjusted r[a]
Overall Hit Rate	0.359 - 3.438	1.726	.60
Overall Firing Rate	1.617 - 5.782	3.327	.66
Overall Hit Proportion	0.222 - 0.828	0.511	.53
Average Opening Time	12.450 - 26.880	18.408	.77
Average Miss Distance	0.778 - 4.383	1.396	.71
Average Target Acquisition Errors	0.750 - 2.318	1.521	.65
Average System Management Errors	0.000 - 0.952	0.177	.51

[a]Average correlation coefficient was adjusted using the Spearman-Brown formula, with the length of the test being equal to the average number of engagements fired.

Summary and Conclusions

A standard test of U-COFT crew gunnery proficiency was used to investigate the effects of 3-, 6-, and 9-hours of M1 U-COFT transition training on gunnery performance. Increasing the number of hours of training on U-COFT resulted in improved gunnery performance on only one of the seven different criterion measures. In addition, the number of hours of reported M1 U-COFT training did not correlate significantly with any of the criterion measures. Additional analyses were conducted to determine if the failure to find a relationship between amount of M1 U-COFT training and gunnery proficiency could have been due to prior U-COFT experience or the predominance of moving tank engagements on the criterion test. Both factors were eliminated as likely causes for the failure to obtain positive results.

Despite the failure to find a relationship between hours of M1 U-COFT training and gunnery proficiency, there was evidence that learning did take place during the nine hours of U-COFT transition training. One bit of evidence was the specific criterion measure on which performance improved--average miss distance. Witmer (1988a) had previously concluded that average miss distance was the most sensitive measure of gunnery performance. The failure to find any improvements in performance on the other six criterion measures may have been the result of their lack of sensitivity rather than the lack of learning. Another bit of evidence is provided by the decreased within group variance on average miss distance and average opening time scores.

The effects of training- and soldier-based variables on U-COFT crew gunnery proficiency were also examined. There was a significant relationship was between the total number of exercises completed in the TC and TC/gunner matrices and five of the criterion performance measures (overall hit rate, overall fire rate, average opening time, average miss distance, and target acquisition errors). Significant relationships were also found between level of reticle aim difficulty attained in the TC/gunner matrix and overall hit rate, average opening time, average miss distance and average target acquisition errors. These results do not necessarily suggest that completing an increased number of U-COFT exercises or attaining a higher reticle aim level in the U-COFT matrices led to increased gunnery proficiency. Given that gunnery proficiency was measured only after three, six, or nine hours of U-COFT training, it is more likely that the more proficient TCs and gunners were able to complete more U-COFT exercises and were able to attain a higher reticle aim level. Unfortunately, this conclusion could not be tested since a pretest of gunnery proficiency was not administered.

The UGPT designed by Hoffman and Witmer (1988) was found to be sufficiently reliable to be used as a means of evaluating crew gunnery proficiency. Spearman-Brown reliability coefficients of at least .70 were found for two of the seven criterion measures (average miss distance and average opening time). Reliabilities greater than .50 were obtained for each of the remaining five measures. Administering the UGPT to crews who had progressed further in each of the U-COFT matrices would probably increase its reliability.

References

Bass, B. A., & Vaughan, J. A. (1966). Training in industry: The management of learning. Belmont, CA: Wadsworth.

Black, B. A., & Abel, M. H. (1987). Review of U.S. armor crew and platoon training in preparation for the 1985 Canadian Army Trophy (CAT) competition (ARI Research Report 1442). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A185 470)

Black, B. A., & Graham, S. E. (1987). Armor crewmen assignment issues and the use of the Unit Conduct of Fire Trainer (UCOFT) in performance prediction (ARI Research Report 1458). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A192 062)

Department of the Army. (1985). M1 Unit Conduct-of-Fire Trainer (U-COFT) training devices support package (Field Circular 17-12-7-1). Washington, DC: Author.

Department of the Army. (1986). Tank combat tables M1 (Field Manual 17-12-1). Washington, DC: Author.

Du Bois, R. S. (1987). The M1 Unit-Conduct of Fire Trainer (U-COFT) as a tank gunnery testing device: A psychometric evaluation. Unpublished Master's Thesis, Western Kentucky University.

Fingerman, P. W., Wheaton, G. R., & Boycan, G. G. (1979). Simulation of a model tank gunnery test (ARI Technical Report 79-A6). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A072 336)

General Electric Company, Defense Systems Division, Simulation and Control Systems Department (1985). Instructor's utilization handbook for the M1 Unit-Conduct of Fire Trainer (U-COFT) (Vol. 1). Orlando, FL: Naval Training Equipment Center, U.S. Army Program Manager Training Devices.

Graham, S. E. (1986). The Unit-Conduct of Fire Trainer (U-COFT) as a medium for assessing gunner proficiency: Test reliability and utility (ARI Research Report 1422). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A169 196)

Hoffman, R. G., & Witmer, B. G. (1988). A UCOFT-based test of M1 gunnery proficiency (Final Draft Report). Alexandria, VA: Human Resources Research Organization.

Hughes, C. R., Butler, W. G., Sterling, B. S., & Berglund, A. W. (1987). M1 Unit Conduct-of-Fire Trainer (TRAC-WSMR-TEA-16-87). White Sands, NM: U.S. Army TRADOC Analysis Command.

Keppel, G. (1982). Design and analysis: A researcher's handbook (2nd Ed.) Englewood Cliffs, NJ: Prentice-Hall.

Silver, N. C., & Dunlap, W. P. (1987). Averaging correlation coefficients: Should Fisher's z transformation be used? Journal of Applied Psychology, 27, 146-148.

Smith, E. P., & Graham, S. E. (1987). Validation of psychomotor and perceptual predictors of armor officer M-1 gunnery performance (ARI Technical Report 766). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A191 333)

Witmer, B. G. (1988a). Device-based gunnery training and transfer between the Videodisk Gunnery Simulator (VIGS) and the Unit Conduct of Fire Trainer (UCOFT) (ARI Technical Report 794). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A197 769)

Witmer, B. G. (1988b). Effects of degraded mode gunnery procedures on the performance of M1 tank gunners (ARI Technical Report 778). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A192 246)

Appendix A

UCOFT Matrices

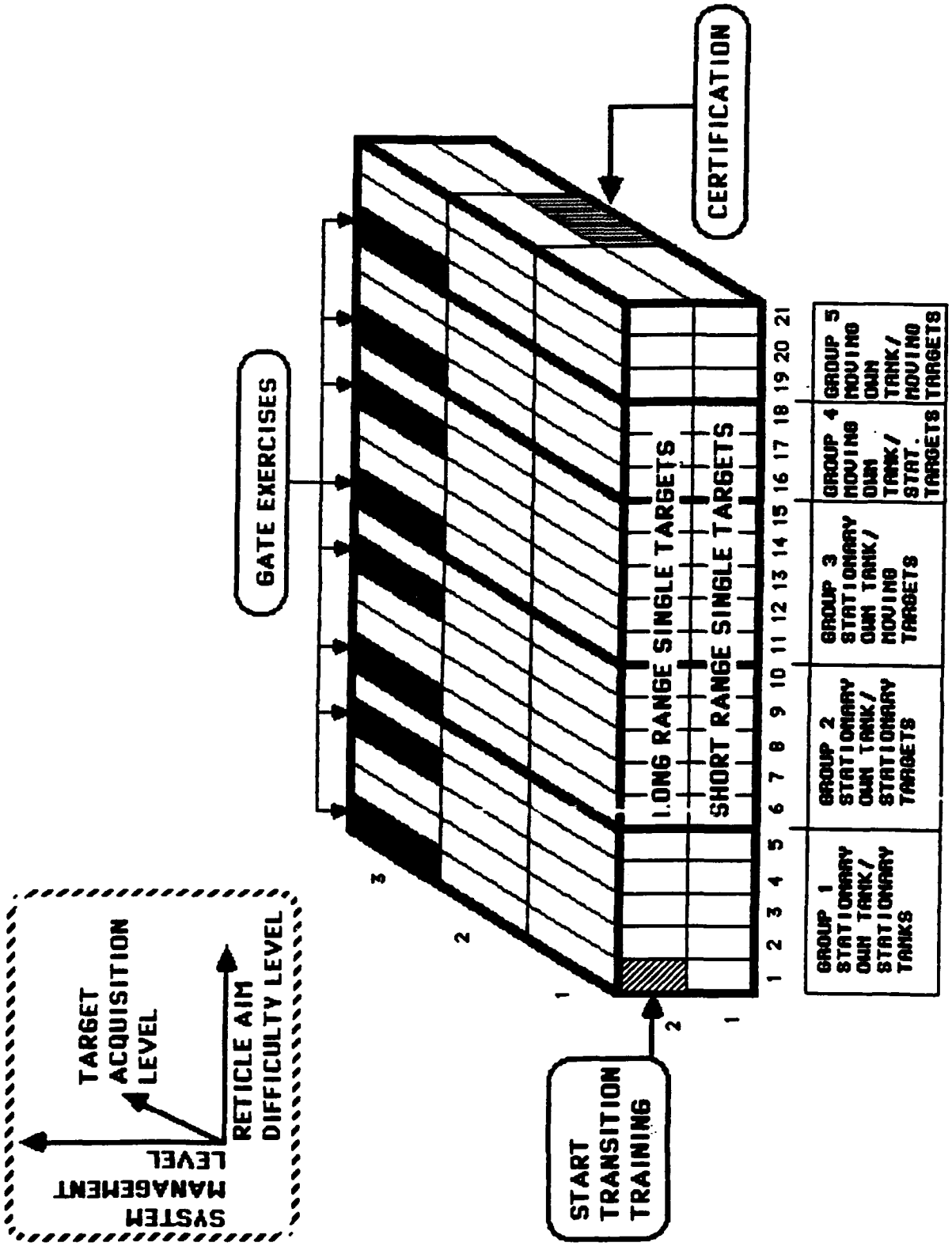

Figure A-1. M1 U-COFT TC training matrix.

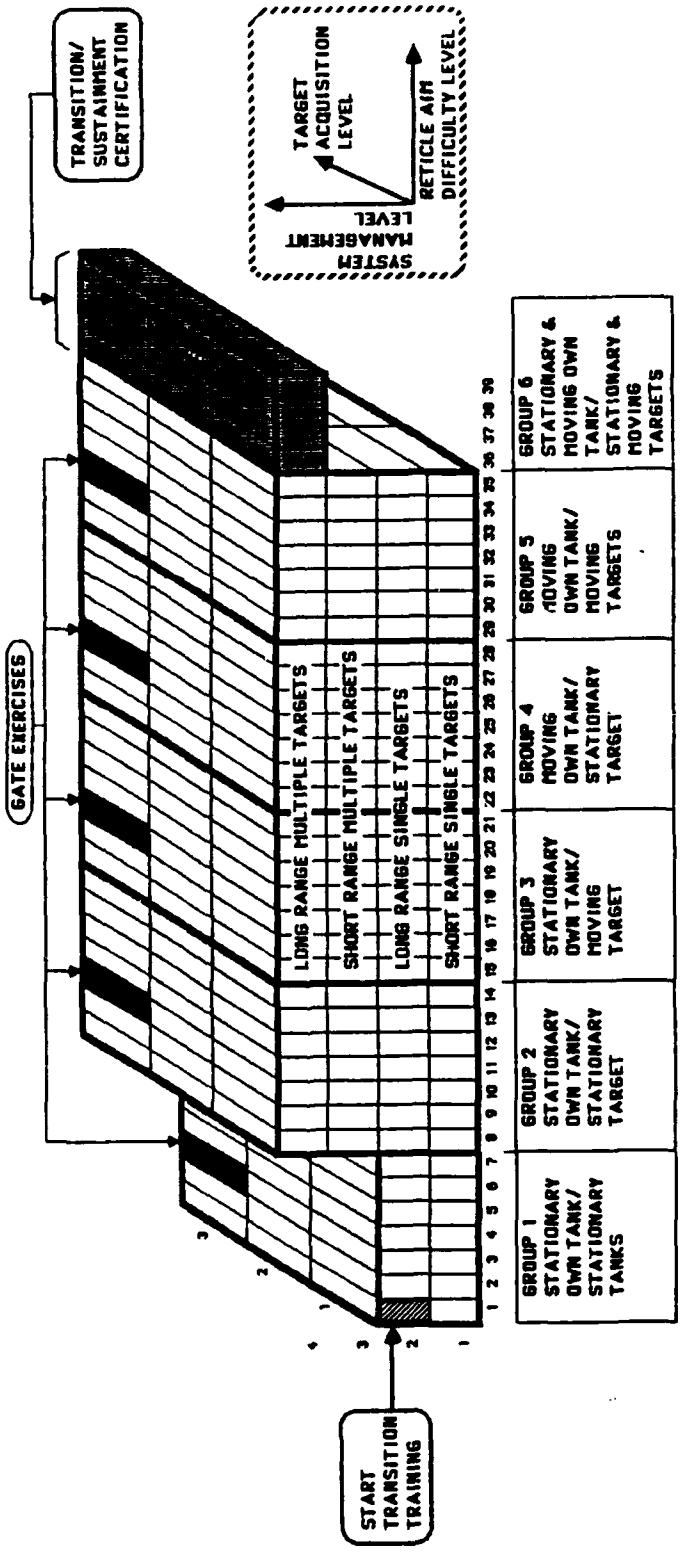

Figure A-2. M1 U-COFT TC/Gunner training matrix.

Appendix B

Engagement Conditions of UGPT Exercises

Table B-1

Engagement Conditions for UCOFT Exercise 34633

Engagement[a]	Own Vehicle Speed	Target Type	Target Range (meters)	Target Speed	Gun	Sight	Ammo	Visibility
1 (1)	25 MPH	Tank	1710	Stationary	Main	GPS	SABOT	Day-reduced
		Helicopter	1850	Stationary	Main	GPS	HEAT	Day-reduced
2 (2)	35 MPH	Tank	1390	Stationary	Main	GPS	SABOT	Day-reduced
		Troops	890	Stationary	COAX	GPS	7.62mm	Day-reduced
3 (3)	25 MPH	Tank	1600	25 MPH	Main	GPS	SABOT	Day-reduced
		APC	1840	25 MPH	Main	GPS	HEAT	Day-reduced
4 (4)	25 MPH	Tank	1820	Stationary	Main	GPS	SABOT	Day-reduced
		M1 Tank	1750	25 MPH	n/a[b]	GPS	n/a	Day-reduced
5 (5)	30 MPH	Tank	1770	Stationary	Main	GPS	SABOT	Day-reduced
		Helicopter	1380	35 MPH	Main	GPS	HEAT	Day-reduced

[a]First number under the heading Engagement indicates the engagement number within that exercise; the number in parentheses indicates the engagement number within the UGPT. [b]Friendly vehicles should not be engaged.

Table B-2

Engagement Conditions for UCOFT Exercise 34611

Engagement[a]	Own Vehicle Speed	Target Type	Target Range (meters)	Target Speed	Gun	Sight	Ammo	Visibility
1 (6)	Stationary	Tank	2100	Stationary	Main	GPS	SABOT	Day-unlimited
		Troops	1090	Stationary	Cal .50	GPS	Cal .50	Day-unlimited
2[b] (7)	Stationary	Tank	1670	Stationary	Main	GPS	SABOT	Day-unlimited
		Tank	1690	Stationary	COAX	GPS	7.62mm	Day-unlimited
		Tank	1930	Stationary	Main	GPS	SABOT	Day-unlimited
3[c] (8)	Stationary	Tank	1730	Stationary	Main	GPS	SABOT	Day-unlimited
		Tank	1980	Stationary	Main	GPS	SABOT	Day-unlimited
		Tank	2020	20 MPH	Main	GPS	SABOT	Day-unlimited
4 (9)	Stationary	Tank	1870	32 MPH	Main	GPS	SABOT	Day-unlimited
		Helicopter	1920	27 MPH	Main	GPS	SABOT	Day-unlimited

[a]First number under the heading Engagement indicates the engagement number within that exercise; the number in parentheses indicates the engagement number within the UGPT. [b]Crews don protective masks to simulate engagement under NBC conditions. [c]Crews simulate firing 3-man engagement (i.e., TC fires engagement without assistance from the gunner).

Table B-3

Engagement Conditions for UCOFT Exercise 34622

Engagement[a]	Own Vehicle Speed	Target Type	Target Range (meters)	Target Speed	Gun	Sight	Ammo	Visibility
1 (10)	Stationary	Tank	1820	Stationary	Main	GPS (TIS)	SABOT	Night-reduced
		Tank	1980	Stationary	Main	GPS (TIS)	SABOT	Night-reduced
2 (11)	Stationary	Tank	1650	Stationary	Main	GPS (TIS)	SABOT	Night-reduced
		Tank	1680	Stationary	Main	GPS (TIS)	SABOT	Night-reduced
		Tank	1960	Stationary	Main	GPS (TIS)	SABOT	Night-reduced
3[b] (12)	Stationary	Tank	1700	23 MPH	Main	GPS (TIS)	SABOT	Night-reduced
		Helicopter	1830	28 MPH	Main	GPS (TIS)	HEAT	Night-reduced
		APC	1820	15 MPH	Main	GPS (TIS)	HEAT	Night-reduced
4[c] (13)	Stationary	Tank	1830	18 MPH	Main	GPS (TIS)	SABOT	Night-reduced
		Tank	1970	21 MPH	Main	GPS (TIS)	SABOT	Night-reduced

[a]First number under the heading Engagement indicates the engagement number within that exercise; the number in parentheses indicates the engagement number within the UGPT. [b]Crews don protective masks to simulate engagement under NBC conditions. [c]Crews simulate firing 3-man engagement (i.e., TC fires engagement without assistance from the gunner).

Table B-4

Engagement Conditions for UCOFT Exercise 31563

Engagement[a]	Own Vehicle Speed	Target Type	Target Range (meters)	Target Speed	Gun	Sight	Ammo	Visibility
1 (14)	15 MPH	Tank	1060	15 MPH	Main	GAS	SABOT	Day-reduced
2 (15)	15 MPH	Tank	1170	15 MPH	Main	GAS	SABOT	Day-reduced
3 (16)	10 MPH	APC	990	10 MPH	Main	GAS	HEAT	Day-reduced
4 (17)	10 MPH	Tank	1430	15 MPH	Main	GAS	SABOT	Day-reduced
5 (18)	10 MPH	M60A3 Tank	880	10 MPH	n/a[b]	GAS	n/a	Day-reduced
6 (19)	15 MPH	Truck	1080	15 MPH	Main	GAS	HEAT	Day-reduced
7 (20)	10 MPH	APC	950	10 MPH	Main	GAS	HEAT	Day-reduced
8 (21)	15 MPH	Tank	1380	10 MPH	Main	GAS	SABOT	Day-reduced
9 (22)	10 MPH	Truck	510	15 MPH	COAX	GAS	7.62mm	Day-reduced
10 (23)	15 MPH	Tank	1310	15 MPH	Main	GAS	SABOT	Day-reduced

[a]First number under the heading Engagement indicates the engagement number within that exercise; the number in parentheses indicates the engagement number within the UGPT. [b]Friendly vehicles should not be engaged.

Appendix C

Biographical Questionnaire

BIOGRAPHICAL QUESTIONNAIRE

S# _____ SSN _____ Date _____

Group: 1 2 Tested as: GNR TC Other Crewmember _____

1. Age_____ yrs. 2. Grade E-_____ 3. GT Score _____

4. Education Level: Circle one

   a. Less than two years b. GED

   c. High School Graduate d. Technical School

   e. Some College f. College Graduate

   g. Other (describe) _____.

5. How long have you been in Armor? _____yrs _____mos

6. Present crew position _____ Time in position _____

7. Time spent as A3 Gunner _____mos Time spent as A3 TC _____mos

8. Time spent as M1 Gunner _____mos Time spent as M1 TC _____mos

9. Time paired with the TC (or gunner) who will assist you today? _____mos

10. Number of separate occasions you have fired the M1 UCOFT _____

    Hours on M1 UCOFT? _____ Present level in the M1 UCOFT matrix? _____

11. Number of separate occasions you have fired the A3 UCOFT _____

    Hours on A3 UCOFT? _____ Present level in the M1 UCOFT matrix? _____

12. Other than UCOFT, what <u>gunnery</u> <u>training</u> have you received since your transition training began?

    Classroom hours? _____

    Other hours? _____

    On vehicle hours? _____

    Type of training? _____

Appendix D

Procedure for Scoring M1 UCOFT Crew Gunnery Proficiency Test

Table D-1

Procedure for Scoring M1 UCOFT Crew Gunnery Proficiency Test

NOTE: With two exceptions, engagements that are marked with a "MISS(D)" or "KILL(D)" are not scored. They should be left blank or coded to indicate a missing value. If there is a "MISS(D)" on a friendly vehicle in either Engagement 4 of Exercise 1, or Engagement 5 of Exercise 4, score step 12 as hitting the friendly target.

Score Engagement 5 of Exercise 4 (the single M1 vehicle) on step 11 only.

For each engagement:

1. Record the number of threat targets presented.
2. Count the number of hits (threat targets only). Tally Cal .50 or COAX percent coverage data as partial hits, e.g., 50% coverage equals .5 hits, 75% coverage equals .75 hits.
3. Count the number of main gun rounds or number of machinegun bursts fired. Use the following tables to convert COAX and Cal .50 rounds to main gun equivalence:

COAX Rounds	Cal .50 Rounds	Main Gun Equivalence
1 - 45	1 - 22	1
46 - 75	23 - 37	2
76 - 105	38 - 52	3

Be sure to check classification errors for rounds fired at non-targets.

(table continues)

Table D-1 (continued)

For each engagement:

4. Calculate firing rate according to the following rules. In each case if (a) the only time available for a main gun round is a "kill time," subtract one second to estimate firing time, and (b) if the rounds are COAX or Cal .50, use kill time minus one second.

   a. If all of the targets are hit:
   Firing rate = number of rounds fired/time for firing the last round.

   b. If rounds are fired, one or more targets are not hit, and a time is available for the last round, calculate:

   A = Total number of rounds fired/time for firing the last round,

   B = Total number of rounds fired/total time (see below), and

   C = (Total number of rounds fired + 1)/total time.

   Use A as the estimate for firing rate unless it is greater than C. If A is greater than C, use estimate B for firing rate.

   c. If rounds are fired, one or more targets are not hit, and a time is not given on the printout, first identify the round that has the largest firing time, i.e., round number 1, round number 2, etc. Then, calculate:

   A = Number of the last round with a time/Time for that round,

   B = Total number of rounds/Total time (see below),

   C = (Total number of rounds + 1)/Total time.

   If B is greater than A, use B for firing rate.
   If A is greater than B and A is less than C, use A.
   If A is greater than B and A is greater than C, use B.

   d. If no rounds are fired, set firing rate to zero.

   NOTE: Multiply firing rate by 60 to facilitate interpretation.

5. Calculate:

   Hit proportion = number of hits (2 above)/number of rounds (3 above).

(table continues)

Table D-1 (continued)

For each engagement:

6. Calculate:

   Hit rate = hit proportion (5 above) times firing rate (4 above).

7. Record opening time (lowest of the fire times). If no round is fired, record the time for the length of the engagement.

Exercise	Engagement	Time	Exercise	Engagement	Time
346331	all	30 sec.	346220	1,4	35 sec.
346110	1	35 sec.	346220	2	50 sec.
346110	2,3	45 sec.	346220	3	45 sec.
346110	4	40 sec.	315631	1,2,4,6,10	30 sec.
			315631	3,5,7,8,9	35 sec.

8. Record number of target acquisition errors, i.e., "C" and "I" errors.

   C - Classification error indicates that the crew failed to engage the more dangerous target first.

   I - Identification error indicates that the crew fired at a non-target.

   2-I - Indicates that the crew did not fire on a target.

NOTE: There can only be one "C" error per engagement. Classification errors and identification errors will be grouped together in the performance records. Always check the number of targets presented and which targets were fired upon to determine which errors were committed more than once. For example, for an engagement in which two targets were presented, and only one target was fired on, 4C-I represents 1-C, 2-I, and 1-I. In other words the crew engaged the less dangerous target first, failed to fire at the most dangerous target, and fired at a non-target.

(table continues)

Table D-1 (continued)

For each engagement:

9. Record number of system management errors, i.e., D, L, M, R, and A errors.

   D - Indicates crew was exposed too long in hull defilade.

   L - Lasing error indicates that the crew failed to activate the LRF before the trigger pull. This is a true error only if the engagement is fired as a precision main gun engagement.

   M - Magnification error indicates that the gunner failed to switch to 10x before the trigger pull.

   R - Indicates that either the ammunition select switch setting or the GAS reticle did not match the ammunition fired.

   A - Ammo error indicates that the crew selected the wrong weapon or ammunition for the type of target presented. (For old programming, ignore these errors when SABOT is fired at helicopter targets.)

   NOTE: System management errors will be grouped together. For example, 2D-L means 1-D and 1-L, and 3D-L means 1-D and 2-L. Always check the type of error to determine which error is committed twice.

10. For each main gun round for which azimuth and elevation error information is available, calculate:

    Miss distance = Square Root (azimuth error^2 + elevation error^2).

    Information may be available for up to three rounds per target, with the information for the first two rounds on the shot pattern printout and the information for the last round on the situation monitor printout.

    Calculate the average miss distance for the engagement as the sum of the miss distances in the engagement divided by the number of rounds with miss distances. Record average miss distance (line 10a), total miss distance (line 10c), and the number of rounds with miss distances (line 10b).

    Do not use rounds fired in defilade in the calculation. These are rounds with very high (e.g. +/- 300 mils) elevation errors.

    If no rounds are fired in the engagement, code as missing or leave blank.

(table continues)

Table D-1 (continued)

For each engagement:

11. For engagement 4 in exercise 1, and engagement 5 in exercise 4, record friendly vehicle hits, either 0 or 1. For the remaining engagements, leave this column blank, or code as missing data.

Across all exercises:

12. Calculate overall firing rate as the weighted average of engagement firing rates, where each engagement is weighted by the number of targets in the engagement. That is, for each engagement multiply line 1 (number of targets) times line 4 (firing rate) and record in line 12. Sum the values in line 12 and divide by the number of targets (38 less the number of targets not scored because of dispersion).

13. Calculate overall hit probability:

    a. Calculate the weighted average of engagement hit percentages, where each engagement is weighted by the number of targets in the engagement. That is, for each engagement multiply line 1 (number of targets) times line 5 (hit proportion) and record in line 13. Sum the values in line 13 and divide by the number of targets.

    b. If one of the friendly targets is hit, multiple the calculated averages by 5/6. If both friendly targets are hit, multiple by 1/2.

14. Calculate hit rate as firing rate (line 12) times hit probability (line 13).

15. Calculate average opening times (line 7).

16. Average the number target acquisition errors. Sum the C and I errors and divide by the number of engagements scored, excluding Exercise 315631 Engagement 5.

17. Average the number system management errors. Sum the D, L, M, R, and A errors and divide by the number of engagements scored, excluding Exercise 315631 Engagement 5.

18. Calculate the average miss distance by averaging the miss distances for each round for which the information is available. Sum 10b and divide by the sum of 10c.

Appendix E

Summary of Biographical Data by Group

Table E-1

Summary of Gunner Background Data by Group

Predictor Measure		Tested After 3 Hours (n=26)	Tested After 6 Hours (n=22)	Tested After 9 Hours (n=20)
Age:	Average	25.08	24.7	26.5
	Range	21-35	21-29	20-38
Rank:	E4	7	6	3
	E5	19	16	17
Education:	Less than 12 years	0	0	0
	GED	1	2	4
	High School Graduate	16	18	15
	Technical School	0	0	0
	Some College	9	2	1
	College Graduate	0	0	0
Years in Armor:	Average	5.04	5.23	5.27
	Range	1.00-12.00	2.00-10.50	1.00-8.00
Years in Position:	Average	1.80	1.89	2.42
	Range	0.80-5.00	0.08-6.00	0.08-6.00
Years as A3 Gunner:	Average	1.81	1.71	2.29
	Range	0.00-5.00	0.00-5.00	0.00-5.00
Years as A3 TC:	Average	0.60	0.33	0.70
	Range	0.00-6.00	0.00-3.00	0.00-4.16
Years as M1 Gunner:	Average	0.06	0.21	0.09
	Range	0.0-0.50	0.00-2.16	0.00-0.50
Years as M1 TC:	Average	0.00	0.25	0.01
	Range	none	0.00-5.00	0-.01
Years with Partner:	Average	0.33	0.32	0.23
	Range	0.00-1.50	0.04-2.00	0.04-1.50
ASVAB CO Score:	Average	112.24	109.59	107.10
	Range	86-139	85-145	85-130
ASVAB GT Score:	Average	110.68	105.40	108.10
	Range	90-126	77-125	80-130
Hours on A3 U-COFT:	Average	83.28	32.53	51.45
	Range	0-300	0-100	0-300
Hours on M1 U-COFT:	Average	4.04	11.05	10.75
	Range	3-15	6-70	8-45
Classroom Hours:	Average	9.18	7.65	6.95
	Range	0-70	0-30	0-80
Vehicle Hours:	Average	24.22	16.95	44.55
	Range	0-90	0-60	0-176

Table E-2

Summary of TC Background Data by Group

Predictor Measure		Tested After 3 Hours (n=26)	6 Hours (n=22)	9 Hours (n=20)
Age:	Average	30.89	32.05	31.55
	Range	25-39	24-42	24-40
Rank:	E-5	3	0	2
	E-6	17	14	15
	E-7	6	8	3
Education:	Less than 12 years	0	0	0
	GED	4	2	4
	High School Graduate	11	10	11
	Technical School	0	1	5
	Some College	11	8	0
	College Graduate	0	1	0
Years in Armor:	Average	10.30	10.19	9.71
	Range	5.75-15.00	4.00-18.00	5.00-15.25
Years in Position:	Average	3.81	3.19	4.70
	Range	0.04-9.50	0.08-9.00	0.16-10.00
Years as A3 Gunner:	Average	1.17	1.24	1.05
	Range	0.00-6.00	0.00-8.00	0.00-4.50
Years as A3 TC:	Average	3.22	2.73	3.85
	Range	0.00-9.00	0.00-8.00	0.00-9.92
Years as M1 Gunner:	Average	.35	0.00	0.00
	Range	0-6	none	none
Years as M1 TC:	Average	0.28	0.75	0.15
	Range	0.00-4.00	0.00-9.00	0.00-1.33
Years with Partner:	Average	0.37	0.37	0.22
	Range	0.04-1.50	0.04-2.00	0.04-1.50
ASVAB CO Score:	Average	110.21	108.52	108.90
	Range	85-135	70-132	87-126
ASVAB GT Score:	Average	111.88	107.67	107.30
	Range	90-138	90-130	82-138
Hours on A3 U-COFT:	Average	91.58	45.09	62.56
	Range	0-312	0-150	0-200
Hours on M1 U-COFT:	Average	23.62	9.36	12.70
	Range	1-150	3-36	8-48
Classroom Hours:	Average	11.77	6.75	6.55
	Range	0-70	0-30	0-80
Vehicle Hours:	Average	26.91	18.14	54.85
	Range	0-90	0-48	0-200

Appendix F

MANOVA Results

Table F-1

Criterion Measure Means by Engagement Type

Criterion Measure	Engagement Type Firing Tank: Target:	Stat. Stat.	Sta. Mov.	Mov. Stat.	Mov. Mov.
Overall Hit Rate		2.323	1.307	2.212	1.574
Overall Firing Rate		0.450	1.194	0.804	1.942
Overall Hit Proportion		0.741	0.419	0.615	0.369
Average Miss Distance		0.450	1.194	0.804	1.942
Average Opening Time		16.801	16.949	13.928	14.449
Average Target Acquisition Errors		2.524	2.788	1.985	0.410
Average System Management Errors		0.136	0.120	0.132	0.218

Table F-2

MANOVA Summary Table for Overall Hit Rate

Source[a]	Mean Square	df	F	p
Between Subjects:				
U-COFT Hours	1.821	2,65	1.012	N.S.
Within Subjects:				
Tank	0.365	1,65	0.260	N.S.
Tank x U-COFT Hours	0.100	2,65	0.071	N.S.
Target	46.291	1,65	36.059	.001
Target x U-COFT Hours	0.920	2,65	0.717	N.S.
Tank x Target	2.250	1,65	2.191	N.S.
Tank x Target x U-COFT Hours	0.177	2,65	0.172	N.S.

[a]U-COFT Hours = hours of transition training on M1 U-COFT (i.e., 3-, 6-, or 9-hours).

Table F-3

MANOVA Summary Table for Overall Firing Rate

Source[a]	Mean Square	df	F	p
Between Subjects:				
U-COFT Hours	9.527	2,65	2.466	N.S.
Within Subjects:				
Tank	65.921	1,65	28.143	.001
Tank x U-COFT Hours	0.632	2,65	0.270	N.S.
Target	1.481	1,65	0.751	N.S.
Target x U-COFT Hours	0.158	2,65	0.080	N.S.
Tank x Target	7.215	1,65	3.766	N.S.
Tank x Target x U-COFT Hours	3.472	2,65	1.813	N.S.

[a]U-COFT Hours = hours of transition training on M1 U-COFT (i.e., 3-, 6-, or 9-hours).

Table F-4

MANOVA Summary Table for Overall Hit Proportion

Source[a]	Mean Square	df	F	p
Between Subjects:				
U-COFT Hours	0.026	2,65	0.383	N.S.
Within Subjects:				
Tank	0.531	1,65	7.945	.006
Tank x U-COFT Hours	0.001	2,65	0.018	N.S.
Target	5.470	1,65	83.115	.001
Target x U-COFT Hours	0.070	2,65	1.061	N.S.
Tank x Target	0.118	1,65	2.486	N.S.
Tank x Target x U-COFT Hours	0.036	1,65	0.753	N.S.

[a]U-COFT Hours = hours of transition training on M1 U-COFT (i.e., 3-, 6-, or 9-hours).

Table F-5

MANOVA Summary Table for Average Miss Distance

Source[a]	Mean Square	df	F	p
Between Subjects:				
U-COFT Hours	2.719	2,57	1.786	N.S.
Within Subjects:				
Tank	17.526	1,57	14.724	.001
Tank x U-COFT Hours	0.369	2,57	0.369	N.S.
Target	51.833	1,57	134.628	.001
Target x U-COFT Hours	0.219	2,57	0.569	N.S.
Tank x Target	2.290	1,57	5.782	.019
Tank x Target x U-COFT Hours	0.318	2,57	0.286	N.S.

[a]U-COFT Hours = hours of transition training on M1 U-COFT (i.e., 3-, 6-, or 9-hours).

Table F-6

MANOVA Summary Table for Average Opening Time

Source[a]	Mean Square	df	F	p
Between Subjects:				
U-COFT Hours	44.886	2,65	2.282	N.S.
Within Subjects:				
Tank	482.851	1,65	24.252	.001
Tank x U-COFT Hours	12.581	2,65	0.632	N.S.
Target	6.394	1,65	0.231	N.S.
Target x U-COFT Hours	1.952	2,65	0.071	N.S.
Tank x Target	3.294	1,65	0.271	N.S.
Tank x Target x U-COFT Hours	7.598	2,65	0.625	N.S.

[a]U-COFT Hours = hours of transition training on M1 U-COFT (i.e., 3-, 6-, or 9-hours).

Table F-7

MANOVA Summary Table for Average Target Acquisition Errors

Source[a]	Mean Square	df	F	p
Between Subjects:				
U-COFT Hours	3.030	2,65	2.832	N.S.
Within Subjects:				
Tank	142.249	1,65	198.645	.001
Tank x U-COFT Hours	0.024	2,65	0.034	N.S.
Target	28.699	1,65	59.158	.001
Target x U-COFT Hours	0.019	2,65	0.038	N.S.
Tank x Target	54.129	1,65	119.381	.001
Tank x Target x U-COFT Hours	1.400	2,65	3.088	N.S.

[a]U-COFT Hours = hours of transition training on M1 U-COFT (i.e., 3-, 6-, or 9-hours).

Table F-8

MANOVA Summary Table for Average System Management Errors

Source[a]	Mean Square	df	F	p
Between Subjects:				
U-COFT Hours	0.255	2,65	2.963	N.S.
Within Subjects:				
Tank	0.147	1,65	2.762	N.S.
Tank x U-COFT Hours	0.036	2,65	0.667	N.S.
Target	0.078	1,65	1.053	N.S.
Target x U-COFT Hours	0.012	2,65	0.164	N.S.
Tank x Target	0.205	1,65	2.951	N.S.
Tank x Target x U-COFT	0.905	2,65	1.373	N.S.

[a]U-COFT Hours = hours of transition training on M1 U-COFT (i.e., 3-, 6-, or 9-hours).