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Research Report 1652

A Review and Annotated Bibliography of Armor Gunnery Training Device Effectiveness Literature

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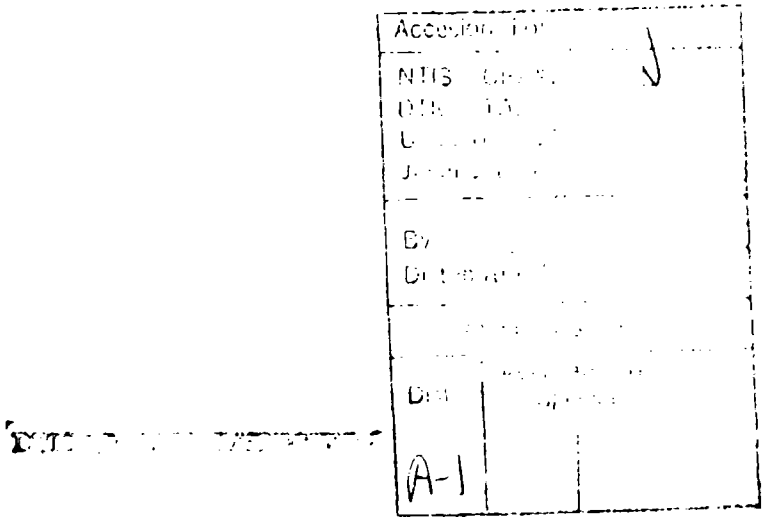

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13. ABSTRACT *(Maximum 200 words)*

This research report supports current efforts by the U.S. Army Armor School (USAARMS) to develop its portion of the Combined Arms Training Strategy (CATS). The report contains a review and annotated bibliography of 39 documents that address tank gunnery training device effectiveness. It also presents a summary of (a) reported findings by types of device (standalone, tank-appended, subcaliber, laser) and areas of training effectiveness (skill acquisition, skill retention, performance prediction, transfer of training) and (b) research limitations (sample size, subjects not random or matched, groups treated differently, device system errors, insufficient amounts of practice, ceiling effects, floor effects, unreliable performance measures) that could possibly affect interpretation of reported findings. Future research requirements are discussed based on the authors' conclusions.

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Research Report 1652

A Review and Annotated Bibliography of Armor Gunnery Training Device Effectiveness Literature

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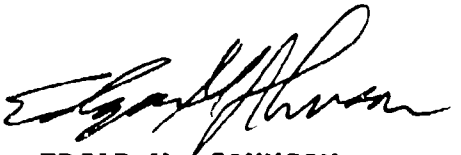
FOREWORD

The U.S. Army is developing a Combined Arms Training Strategy (CATS) to provide direction and guidance on total force training and the mix of training resources required to achieve and sustain combat-ready forces. As part of CATS, the U.S. Army Armor School (USAARMS) is examining institutional and unit training events, their frequency, and the resources required to train to standard. To develop an effective Armor CATS requires precise and empirical validation of gunnery training devices. Lack of adequate information about the training effectiveness of tank gunnery training aids, devices, simulators, and simulation (TADDS) might limit the utilization of a CATS for armor.

This research was performed by the Fort Knox Field Unit, U.S. Army Research Institute for the Behavioral and Social Sciences (ARI), under the task entitled "Strategies for Training and Assessing Armor Commanders' Performance with Devices and Simulations (STRONGARM)." This task is supported by a Memorandum of Agreement dated 16 January 1989 titled "The Effects of Simulators and Other Resources on Training Readiness" with the U.S. Army Training and Doctrine Command (TRADOC), U.S. Army Materiel Command (AMC), U.S. Army Armor Center (USAARMC), Fort Knox, and ARI.

The research supports efforts by the USAARMS to develop an Armor CATS. In addition to an annotated bibliography of tank gunnery device documents, the report provides a summary of (a) major findings by type of device (standalone, tank-appended, subcaliber, and laser) and four areas of training effectiveness (skill acquisition, skill retention, performance prediction, and transfer of training), and (b) eight research limitations that could possibly affect interpretation of the reported major findings.

The results of this research were provided to CATS Division, 16th Cavalry Regiment, USAARMS, Fort Knox, Kentucky, in August 1993. They also were provided to the U.S. Army TRADOC Analysis Command at White Sands Missile Range (TRAC/WSMR) to support its ongoing Simulation/Simulator (SIM2) study to advance the development of future training strategies.



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A REVIEW AND ANNOTATED BIBLIOGRAPHY OF ARMOR GUNNERY TRAINING DEVICE EFFECTIVENESS LITERATURE

EXECUTIVE SUMMARY

Requirement:

This research supports the requirement by the U.S. Army Armor School (USAARMS) to develop its portion of the Combined Arms Training Strategy (CATS) for Armor. It provides a comprehensive review and annotated bibliography of literature on the training effectiveness of tank gunnery devices.

Procedure:

Thirty-nine documents addressing the training effectiveness of 15 tank gunnery training devices were reviewed and annotated. Major findings reported by the authors were summarized by four types of gunnery device (standalone, tank-appended, subcaliber, laser) and areas of training effectiveness (skill acquisition, skill retention, performance prediction, transfer of training). Based on this review, eight limitations (sample size, subjects not random or matched, groups treated differently, device system errors, insufficient amounts of practice, ceiling effects, floor effects, unreliable performance measures) that could possibly affect interpretation of the findings were identified for each report. Future research requirements are presented based on the summary results.

Findings:

The research provides strong evidence that (except for the 3A102B laser) tank gunnery skills are learned on all the training devices reviewed. Some evidence of skill retention exists for the Conduct of Fire Trainers (COFT) and Platoon Gunnery Trainer (PGT), but no evidence for the other types of devices. Most of the standalone and tank-appended devices provide a performance prediction capability, but no such evidence exists for subcaliber (except the cal .22) and laser devices. There is some evidence of training transfer for all devices except three standalone (PGT, Videodisk Gunnery Simulator [VIGS], and TOPGUN) and one laser device (3A102B).

Utilization of Findings:

These findings provide training effectiveness data that can be used by the USAARMS in the development of the Armor CATS. They help to meet the goal established by the U.S. Army Training and Doctrine Command (TRADOC) of increased training effectiveness and reduced training costs by the integration of training aids, devices, simulators, and simulations (TADDS) into institutional and unit training. These findings also provide a basis for a U.S. Army Research Institute for the Behavioral and Social Science (ARI) research program to improve the Army's capability to provide effective training using the present and future inventory of tank gunnery training devices.

A REVIEW AND ANNOTATED BIBLIOGRAPHY OF ARMOR GUNNERY TRAINING DEVICE EFFECTIVENESS LITERATURE

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A REVIEW AN. ANNOTATED BIBLIOGRAPHY OF ARMOR GUNNER· TRAINING DEVICE EFFECTIVENESS LITERATURE

Introduction

Overview

This report provides a review and annotated bibliography of research and evaluation documents that have been published on the training effectiveness of tank gunnery devices. The 39 documents reviewed include government agency reports as well as reports by civilian contractors. Both types of documents include specific information on training device effectiveness that may not have received broad circulation. Documents that are not generally available, but that have been included in the review, include research reports published by the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI), concept evaluation program (CEP) reports by the U.S. Army Armor and Engineer Board, training effectiveness analysis (TEA) reports by the U.S. Army Training and Doctrine Command (TRADOC) System Analysis Activity (TRASANA), and research or analytical reports by contractors and published under ARI auspices (e.g., Human Resources Research Organization [HumRRO]). Although these reports can usually be located in databases such as the National Technical Information Service (NTIS) and Defense Technical Information Center (DTIC), they are often not readily available to military strategists. The open literature was not searched because reports on gunnery devices are not normally in the purview of academia.

Research Objective

It was the intent of the authors to prepare a document that reported the training effectiveness of gunnery devices in such detail that the reader would see it as an introduction into the area rather than just an identification of the documents he or she might want to read. Three decisions were made about the nature and content of this work. First, it was decided that the reader was a trained researcher preparing to do research with some gunnery training device, or a trained professional, such as an Operations Research Systems Analyst (ORSA), with a significant need to be aware of the extent and nature of training device effectiveness literature. Thus, each annotated review contains considerable detail about the research or evaluation conducted. It was also decided to limit the reviews as much as possible to reports that discussed tank gunnery training. Second, it was decided that the reader would want to know what has or has not been determined about the training effectiveness of the gunnery devices. Thus, major findings were extracted from the documents and summarized as they relate to four areas of training device effectiveness: (a) skill acquisition, (b) skill retention, (c) performance prediction, and (d) training transfer. This summary of findings is presented in separate tables by types of gunnery device (standalone, tank-appended, subcaliber, laser). Last, it was decided that the reader may want to know about limitations

that affect the major findings presented in each report. Thus, an assessment of the findings was conducted in terms of eight potential error sources that threaten validity. This assessment is presented in a summary table with limitations identified by report reference number, and an additional table that identifies the gunnery training devices involved in each specific reference.

Report Organization

The report is organized into two principal sections and two appendixes. The first section provides a summary of the authors' major findings. These findings are shown in separate tables by type of gunnery device (standalone, tank-appended, subcaliber, and laser) and how they relate to one of four areas of training effectiveness (skill acquisition, skill retention, performance prediction, and training transfer). This is followed by a brief descriptive summary of the reported findings. The second section provides a summary of limitations that could lead to possible misinterpretation about the effectiveness of each gunnery device. These limitations are (a) small sample size, (b) subjects not random or matched, (c) groups treated differently, (d) device system errors, (e) insufficient amounts of practice, (f) ceiling effects, (g) floor effects, and (h) unreliable performance measures. Again, a short descriptive summary of the limitations is provided following the tables. In Appendix A, an annotated description of each document reviewed is provided, followed by a list of the reports. In Appendix B, a summary description of each training device is provided, along with the related references.

Major Findings on Armor Gunnery Training Devices

Approach

Types of Training Devices. To provide a summary of major findings on gunnery training devices, the devices were organized under four separate classifications or types. Gunnery devices that did not require the actual use of a tank were classified as standalone devices. These devices included:

(1) M1 Conduct-of-Fire Trainers (COFTs), the Unit (U-COFT), Institutional (I-COFT), and Mobile (M-COFT) versions;

(2) Platoon Gunnery Trainer (PGT);

(3) Videodisk Gunnery Simulator (VIGS);

(4) TOPGUN; and

(5) Three Burst-on-Target (BOT) trainers (17-4 [Green Hornet], 17-4M [Modified], and 17-4B [Wiley].

Gunnery devices that required affixing various computer instrumentation to a tank were classified as tank-appended devices. These devices included:

(1) Guard Unit Armory Device Full-crew Interactive Simulation Trainer - Armor (GUARDFIST I),

(2) Tank Gunnery and Missile Tracking System (TGMTS), and

(3) SAAB BT-41.

Gunnery devices that required firing subcaliber ammunition were classified as subcaliber devices. These devices included:

(1) Cal .22,

(2) 7.62mm Coaxial Machine Gun,

(3) M179 Telfare (Cal .50), and

(4) Tank Precision Gunnery Inbore Device (TPGID).

Gunnery devices that required firing a laser from a tank were classified as laser devices. These included:

(1) Multiple Integrated Laser Engagement System/Thru-Sight Video (MILES-TSV),

(2) M55 Laser, and

(3) 3A102B Laser.

Areas of Training Effectiveness. The major findings from each document reviewed were then organized under one of four areas of device training effectiveness; skill acquisition, skill retention, performance prediction, and skill transfer (Morrison, Drucker, & Campshure, 1991). Entries under the heading of skill acquisition include empirical results that describe the extent to which performance on the device improves with repeated practice. The skill retention entries relate to the extent to which gunnery skills acquired with the device are retained (or resist decay) over no practice intervals. The performance prediction entries include empirical findings that clarify the relationship between device performance and performance on the operational equipment. Positive correlations, for example, provide evidence for the commonality of skills between the two different contexts, and therefore would be a necessary (but not sufficient) condition for training transfer. The entries under training transfer refer to empirical evidence that relates transfer of skills acquired on a training device to actual tank gunnery performance. This entry also includes both within-device and between-device transfer of training.

Results

The major findings on armor gunnery training devices are summarized by the four device types and four areas of training effectiveness. These findings are presented below in Tables 1-4.

Table 1

Summary of Major Findings on Standalone Armor Gunnery Training Devices

Skill Acquisition	Skill Retention	Performance Prediction	Transfer of Training
M1 Conduct-of-Fire Trainer (COFT) Gunner performance under emergency mode conditions significantly degraded firing time and aiming error, especially in long-range engagements (See Reference 2). Wearing protective mask and gloves did not significantly affect nor further degrade U-COFT performance under normal or emergency mode conditions (Ref 2). Pre/posttest comparison of U-COFT trained CAT crews showed significant improvement in both gunnery speed and accuracy performance measures for each of two distinct training periods on the U-COFT (Ref 4). Gunners paired with a U-COFT experienced TC had a significantly better combined U-COFT test and retest hit rate, identification [ID] time, and Reticle Aim, Target Acquisition, and System Management scores (Ref 10). Pre/posttest comparison of Excellence in Armor [EIA] soldiers who trained on I-COFT showed significant improvement in speed and accuracy of gunnery performance (Ref 11). Analysis of EIA soldier performance on I-COFT showed that gunnery skills related to accuracy grow quickly while skills related to engagement speed grow more slowly (Ref 11). The U-COFT is an effective training device provided problems identified during pre-fielding tests are fixed (Ref 21).	M1 Conduct-of-Fire Trainer (COFT) Two of five M1 qualified TC/gunner pairs who received three weeks of U-COFT sustainment training showed a definite proficiency loss when retested ten weeks later (Ref 6). Two TC/gunner pairs who had been transition trained on the U-COFT for three weeks showed no proficiency loss when retested after three weeks (Ref 6). Seventy-four percent [74%] of U-COFT trained crews that reached reticle aim group 3 or better had higher Tank Table [TT] VIII scores on their second firing, performed about 90 days later (Ref 17). Sixty-two percent [62%] of U-COFT trained crews that did not reach reticle aim group 3 had lower scores on their second TT VIII firing, performed about 90 days later (Ref 17). Relationships between M-COFT Hit Rate and TT VIII were robust, with either one-day or 30-day intervals between M-COFT testing and TT VIII firing (Ref 33).	M1 Conduct-of-Fire Trainer (COFT) U-COFT firing time was significantly related to gunner time in military, suggesting the slowing of response time with age (Ref 2). A significant correlation was found between speed measures on a standardized U-COFT test given after U-COFT training and CAT performance, but none between U-COFT measures of accuracy and CAT performance (Ref 4) Results of Operational Test [OT] III of U-COFT found no correlation between performance on a standardized U-COFT test given after training and performance on a live-fire TT VIII gunnery exercise (Ref 7). A composite of U-COFT reticle aim level and time in crew predicted which crews in a battalion would qualify on TT VIII, but this result was not replicated with a second battalion's TT VIII firing (Ref 8). The reliability of all criterion measures in a U-COFT gunnery proficiency test [UGPT] exceeded .50, with the reliability of two measures exceeding .70 (Ref 9). The reliability of six of nine criterion measures in a U-COFT test of gunner proficiency exceeded .70, with reliability of three measures exceeding .80 (Ref 10). Poor reliability was found in a U-COFT test of gunner proficiency for azimuth errors [.42], elevation errors [-.07], and the U-COFT System Management scores [.11] (Ref 10).	M1 Conduct-of-Fire Trainer (COFT) Posttest measures of U-COFT trained Canadian Army Trophy [CAT] crews' engagement speed were positively related to speed of engagement in the CAT competition (Ref 4). The top-scoring U.S. Army unit participating in the CAT competition received the greatest amount of U-COFT training (Ref 4). The U-COFT training program was found training transfer effective. The relationship of four of six performance measures on a live-fire test was significant (Ref 7). No significant difference in amount of training transfer effectiveness was found between a U-COFT training program and a M179 Telfare training program (Ref 7). Based on percentage of first round hits, the average time to first round firing, and average time to acquire the first target on a live-fire test, the U-COFT training program was found satisfactory for gunnery skills sustainment (Ref 7). U-COFT crew reticle aim level was correlated significantly with average total score and hit rate on TT VIII. TC reticle aim level also correlated significantly with the average total score on TT VIII (Ref 8). A significant relationship was found between total number of U-COFT TC and crew matrix exercises completed and five UGPT measures [Hit Rate, Fire Rate, and average opening time, miss distance, acquisition error (Ref 9).

Table 1 (Cont'd)

Skill Acquisition	Skill Retention	Performance Prediction	Transfer of Training
M1 Conduct-of-Fire Trainer (COFT)	M1 Conduct-of-Fire Trainer (COFT)	M1 Conduct-of-Fire Trainer (COFT)	M1 Conduct-of-Fire Trainer (COFT)
The U-COFT training program provides a satisfactory level of training effectiveness (Ref 21). The U-COFT will partially alleviate inability of tank crews to sustain their gunnery proficiency throughout the year due to resource constraints (Ref 21). The U-COFT will provide a medium by which units can train newly arrived personnel and cross-train crew members regularly (Ref 21). The U-COFT was found to provide excellent TC/gunner critical gunnery skills training. However, it was limited in terms of target acquisition and observation of target hit training (Ref 28). Firing under degraded mode condition on the U-COFT had a significant adverse effect on the performance of experienced armor crewmen. The most dramatic decrements occurred with the use of the Gunner's Auxiliary Sight [GAS] or when long-range moving targets were engaged without the laser rangefinder [LRF] (Ref 38). Gunner performance decrements due to firing under degraded conditions on the U-COFT did not quickly disappear with limited practice, suggesting that the decrements are not easily eliminated (Ref 38). Comparison of two blocks of 27 engagements performed on M1 U-COFT by M60A3 gunners showed significant improvement in measures of speed and accuracy, with significant decreases in ID time, open time, hit time, and number of system errors (Ref 39).		A global measure of controlled tracking skill [interval from the gunner first getting the reticle on target to the point where he loses to the target for range] was found successful in predicting speed and accuracy of gunnery performance on the I-COFT (Ref 11). U-COFT matrix progress and amount of U-COFT training relate significantly to TT VIII gunnery performance, but they are insufficient as predictors of TT VIII performance (Ref 17). TT VIII performance can be predicted from combination of M-COFT Hit Rate using the UGPT and demographic variables [TC vision and crew years of military service]. However, results are not suitable for training policy revision until they can be replicated (Ref 33). M-COFT training improved the speed and accuracy of GUARDFIST I posttest scores, whereas training on GUARDFIST I improved only the speed of M-COFT posttest scores. Measures of M-COFT and GUARDFIST I accuracy did not correlate significantly (Ref 34) Biographical variables are not reliable predictors of degraded mode gunnery performance on U-COFT. Also gunner age was correlated negatively with U-COFT performance, suggesting declining psychomotor abilities for older gunners (Ref 38). Soldiers who fired more accurately on U-COFT also did so on VIGS; thus U-COFT is a good predictor of VIGS performance and vice versa. Measure of speed were not correlated significantly (Ref 39).	A significant relationship was found between U-COFT crew reticle aim level attained and four UGPT measures [Hit Rate, average opening time, average miss distance, and average acquisition error] (Ref 9). U-COFT matrix progress, unit gunnery classes, and motor pool training were highly related to total scores on TT VIII. These types of training, plus Tank Crew Proficiency Course [TCPC] and Tank Crew Gunnery Skills Test [TCGST] were significantly related to average open times on TT VIII, though each type accounted for less than 10% of total variation in TT VIII performance (Ref 16). U-COFT trained crews had significantly faster opening times for both the offensive/defensive tasks on TT VIII. For offensive tasks, they fired their first round about 1.5 seconds faster, and achieved same percentage of first round hits [about 80%] (Ref 17). U-COFT trained crews that did not live-fire TT VI [average of 12.5 rounds] performed better on TT VIII than non U-COFT trained crews who did live-fire TT VI (Ref 17). A trend towards better performance on TT VIII was found for U-COFT trained crews as opposed to crews not trained on the U-COFT. U-COFT trained crews scored higher on all four measures; the significant differences being the percentage of first round hits and percentage of targets hit per round expended (Ref 24). U-COFT training may compensate for lower TT VIII scores due to decreased number of rounds (Ref 24).

Table 1 (Cont'd)

Skill Acquisition	Skill Retention	Performance Prediction	Transfer of Training
M1 Conduct-of-Fire Trainer (COFT) U-COFT training produced substantial improvement in acquisition time, engagement time, and first round hits (Ref 6). I-COFT training improved gunnery performance [speed, accuracy, hit rate] (Ref 27). Mental practice did not improve I-COFT performance (Ref 27).	M1 Conduct-of-Fire Trainer (COFT)	M1 Conduct-of-Fire Trainer (COFT)	M1 Conduct-of-Fire Trainer (COFT) On the average, U-COFT trained crews took three seconds longer to engage the first target on TT VIII than the slowest of crews trained using the SAAB BT-41 or MILES-TSV (Ref 28). M-COFT Hit Rate correlated significantly with TT VIII scores, and the greater the number of M-COFT training exercises used to calculate Hit Rate, the stronger the correlation with TT VIII live-fire performance (Ref 33).
Platoon Gunnery Trainer (PGT) The PGT (prototype) was found highly successful in improving the platoon tactical and gunnery proficiency of Armor Officer Basic Course (AOBC) students (Ref 19).	Platoon Gunnery Trainer (PGT)	Platoon Gunnery Trainer (PGT) Linear trend analyses indicated that platoon performance on the PGT improved across trials in approximate proportion to the amount of training received on the device (Ref 19).	Platoon Gunnery Trainer (PGT)
Videodisk Gunnery Simulator (VIGS) A significant reduction in training time was achieved on M1 VIGS using Above-Real Time Training (ARTT) with performance equal to or surpassing real-time performance (Ref 12). Pre/posttest comparison of soldiers trained on the MK60 [prototype] VIGS showed significant improvement on seven measures of M60A1 tank gunnery performance (Ref 14). Improvement in MK60 pre and posttest performance was attributable directly to the speed of achieving target hits (Ref 14). The MK60 was found to reinforce the procedural aspects of M60A1 gunnery performance (Ref 14).	Videodisk Gunnery Simulator (VIGS) An M1 VIGS retention test given 10 weeks following device training did not lead to significantly better within-device retention scores when the accuracy criterion was relaxed (Ref 22).	Videodisk Gunnery Simulator (VIGS) The test-retest reliability of the MK60 [prototype VIGS] was weak, as was the predictive validity of MK60 scores for dry-fire and live-fire performance (Ref 14). Correlations on six M1 VIGS and TOPGUN criterion measures revealed that VIGS cannot predict performance on TOPGUN or vice versa (Ref 35). The correlations between M1 VIGS and I-COFT performance scores [reticle aim, target acquisition], as well as time to fire [speed measure] indicated that VIGS can be used to predict similar I-COFT performances (Ref 35) Low correlation between M1 VIGS and I-COFT hit percentage indicated that VIGS cannot be used to predict performance accuracy on I-COFT (Ref 35)	Videodisk Gunnery Simulator (VIGS) The M1 VIGS group that trained under random time accelerations using ARTT had significantly better gunnery indexes [UGPT] and hit/miss percentages in transfer (Ref 12). The correlation between MK60 pretest scores and percent of hits during an M60A1 live-fire test was not significant [i.e., no evidence of training transfer] (Ref 14). M1 VIGS practice with a more difficult or easier accuracy criterion did not lead to significantly better within-device transfer scores when the criterion was relaxed (Ref 22). Significant transfer was found between the M1 VIGS and TOPGUN, with no superiority for either training device (Ref 35).

Table 1 (Cont'd)

Skill Acquisition	Skill Retention	Performance Prediction	Transfer of Training
Videodisk Gunnery Simulator (VIGS) M1 VIGS practice with an accuracy criterion more difficult than the test criterion yielded greater hit percentages but slower firing times (Ref 22). M1 VIGS performance significantly improved over four trials [41 target engagements each] for five of six criterion measures [fire time, kill time, elevation errors, hit percentage, performance score]. Only the azimuth score was not statistically significant (Ref 35). Significant improvements in gunnery performance were shown on M1 VIGS as a function of training, with significant decreases in ID time, opening time, hit time, and number of system management errors. The VIGS can be used to cross-train M60A3 soldiers (Ref 39).	Videodisk Gunnery Simulator (VIGS)	Videodisk Gunnery Simulator (VIGS)	Videodisk Gunnery Simulator (VIGS) Soldiers who fired more accurately on the M1 VIGS also did so on M1 U-COFT, but measures of speed were not significantly correlated [i.e., transfer of training between devices was not indicated] (Ref 39).
TOPGUN Soldiers trained on Battlesight [a prototype TOPGUN] showed a significant improvement across trials in number of hits and number of first round hits. No significant differences were found in the performance between experienced and inexperienced soldiers (Ref 1). Soldiers trained on Battlesight using the standard kill zone [100% of target area] were significantly more accurate than those who used a reduced kill zone [50%] (Ref 1). Soldiers using a revised Battlesight video game format improved firing accuracy across trials while those using the standard game format did not show such improvement (Ref 1).	TOPGUN	TOPGUN TOPGUN was found to be a reliable predictor of U-COFT performance, with greater correlation for speed than accuracy (Ref 13). Correlations on six TOPGUN and M1 VIGS criterion measures revealed that TOPGUN can not be used to predict performance on VIGS and vice versa (Ref 35). TOPGUN performance on five of six criterion measures indicated significant stability and reliability of measures (Ref 35).	TOPGUN Training transfer was found from TOPGUN to U-COFT in terms of accuracy on stationary targets (Ref 13). Soldiers trained on TOPGUN did not perform significantly different than a control group on any of six gunnery criterion measures when tested on the I-COFT (Ref 18). TOPGUN speed measures were found to correlate significantly with similar I-COFT measures, but not for accuracy (Ref 35). Significant between-device transfer occurred between TOPGUN and the M1 VIGS, with no superiority for either device (Ref 35).

Table 1 (Cont'd)

Skill Acquisition	Skill Retention	Performance Prediction	Transfer of Training
TOPGUN Trial effects on TOPGUN showed that hit percentages using a MIXed and DIFFicult approach increased across blocks while mean fire time, mean elevation error, and mean azimuth error decreased. The PROGressive approach showed declining hit percentages and increasing fire times (Ref 5). Test results indicated that learning occurred with practice on TOPGUN. Mean score for all gunnery criterion measures were significant for both MIXed and DIFFicult training groups (Ref 5). Test results indicated that speed and accuracy of performance on stationary and moving targets improved significantly during TOPGUN training (Ref 13). Pre/posttest comparison of TOPGUN performance showed significant improvement on five of six criterion measures for both experienced and inexperienced gunners (Ref 18). Performance improvements on TOPGUN were not significantly different using either a structured or free-play training approach (Ref 18). A significant improvement in proficiency was found from both TOPGUN and I-COFT pre/posttest on all six gunnery criterion measures (Ref 18). TOPGUN and M1 VIGS skill acquisition proceeded slowly but consistently, at equal rates, and performance had not stabilized after 123 target engagements (Ref 35).	TOPGUN	TOPGUN	TOPGUN

Table 1 (Cont'd)

Skill Acquisition	Skill Retention	Performance Prediction	Transfer of Training
Burst-on-Target (BOT) Trainers Results showed that M60A1 trainees who used the 17-4 BOT trainer [Green Hornet] reached the 90% proficiency criterion faster than trainees using a 17-4M [modified] or 17-4B [Wiley] (Ref 36). M60A1 trainee gunner proficiency increased with practice on all three BOT trainers. Percentage of hits by the Wiley group was below that of the 17-4 and 17-4M groups, and their times between shots were longer (Ref 36).	Burst-on-Target (BOT) Trainers	Burst-on-Target (BOT) Trainers	Burst-on-Target (BOT) Trainers Transfer test results indicated no significant difference between groups who used the 17-4, 17-4M, or Wiley BOT trainers in terms of accuracy on a M60A1 live-fire test (Ref 36). Each BOT trainer [17-4, 17-4M, Wiley] led to positive transfer of training in terms of speed in applying BOT on a M60A1 live-fire test (Ref 36).

Table 2

Summary of Major Findings on Tank-Appended Gunnery Training Devices

Skill Acquisition	Skill Retention	Performance Prediction	Transfer of Training
GUARDFIST I GUARDFIST I trained crews had higher mean crew cut scores on a live-fire Tank Table (TT) VIII; thus, indicating that the device fails to train tank crew gunnery procedures (See Reference 23). GUARDFIST I and M-COFT can be used interchangeably to improve the speed of device-based tank gunnery engagements, whereas M-COFT should be used for improving accuracy (Ref 34).	GUARDFIST I	GUARDFIST I High pretest scores on GUARDFIST I or M-COFT predicted training success on the same device which, in turn, predicted posttest scores on the alternative device (Ref 34). Trial Efficiency, a measure of tank crews' speed of advancement through the GUARDFIST I training matrix, was significantly related to a host of M-COFT posttest scores (Ref 34). Advancement into the M-COFT matrix was the best predictor of GUARDFIST I posttest scores (Ref 34).	GUARDFIST I Results from a GUARDFIST I modified Tank Table VIII revealed that GUARDFIST I trained crews from two M1 Army National Guard [ARNG] battalions had higher mean net-point score estimates than Non GUARDFIST I trained crews (i.e., demonstrating positive training transfer] (Ref 23). For crews that received sufficient training on offensive engagements on GUARDFIST I, training transferred to M-COFT speed of engagement [Fire-Rate], but not accuracy [Hit Rate] (Ref 34).
TGMTS The TGMTS was as effective as an M55 Laser and Cal .22 device in providing initial gunnery training of M60-A3 trainees (Ref 31). The more experienced M60A3 gunners tested on TGMTS had higher hit probabilities and faster engagement times (Ref 37). Target hit probability during TGMTS testing significantly decreased as range-to-target distance increased (Ref 37). TC/gunner pairs engaged targets faster with the TGMTS after testing, but firing accuracy did not improve from one film [nine engagements] to the next two films (Ref 37).	TGMTS	TGMTS TGMTS can be used to reliably and accurately measure M60A3 TC/gunner performance (Ref 37).	TGMTS TGMTS trained soldiers had significantly faster precision engagement times [average 1.5 seconds] than M55 Laser and Cal .22 device trained soldiers, as measured by training transfer results on a modified TT VI [day only] (Ref 31). There was no significant difference between TGMTS trained and M55 Laser or Cal .22 trained soldiers in terms of target effect and completion of crew duties, as measured by training transfer results (Ref 31).
SAAB BT-41 The SAAB BT-41 provided crews with a precision gunnery capability and was effective for gunner training. Load-interaction was limited (Ref 28).	SAAB BT-41	SAAB BT-41	SAAB BT-41 The SAAB BT-41 trained company fired TT VIII as well as the tank company that trained for TT VIII using live-fire ammunition (Ref 28).

Table 3

Summary of Major Findings on Subcaliber Gunnery Training Devices

Skill Acquisition	Skill Retention	Performance Prediction	Transfer of Training
Caliber .22 M60A1 tank gunnery performance on a mini-tank range using Cal .22 ammo was more accurate, efficient, and less costly than firing on a 7.62mm Coaxial Machine Gun [single shot] range (See Reference 3). The Cal .22 device was as effective as the TGMTS and M55 Laser in providing initial gunnery training of M60A3 trainees (Ref 31).	Caliber .22	Caliber .22 Cal .22 opening time and percent of first round hits were the best predictors of M60A3 TT VIII accuracy measures while Cal .22 opening time and total time were the best predictors of M60A3 TT VIII speed measures (Ref 20).	Caliber .22 No significant differences were found between M60A1 gunners who used the mini-tank range and Cal .22 ammo in preliminary subcaliber training and gunners who used the 7.62mm Coaxial Machine Gun [single shot] on TT IV, V, or VIII (Ref 3). M60A1 gunners who used the mini-tank range and Cal .22 ammo in preliminary subcaliber training, compared to gunners who used the 7.62mm Coaxial Machine Gun [single shot], had faster first round time-to-fire scores on TT IV, achieved the best hit scores on TT IV and VIII, and attained the best overall scores on TT VIII with no tank crew errors (Ref 3). M60A3 gunnery performance on a mini-tank range (1/60th scale + Cal .22] was significantly related to similar measures on TT VIII (Ref 20).
7.62mm Coaxial Machine Gun M60A1 tank gunnery on a 7.62mm Coaxial Machine Gun range was less accurate, efficient, and more costly than firing Cal .22 ammo on a mini-tank range (Ref 3).	7.62mm Coaxial Machine Gun	7.62mm Coaxial Machine Gun	7.62mm Coaxial Machine Gun M60A1 gunners who used a 7.62mm Coaxial Machine Gun [single shot] range in preliminary subcaliber training, compared to gunners who fired cal .22 ammo on a mini-tank range, had slower first round time-to-fire scores on TT IV, achieved lower hit scores on TT IV and VIII, and had lower overall scores on TT VIII with more tank crew errors (Ref 3).
M179 Telfare (Cal .50) The M179 Telfare training program maintained soldiers' proficiency on M1 gunnery tasks (Ref 7).	M179 Telfare (Cal .50)	M179 Telfare (Cal .50)	M179 Telfare (Cal .50) Pre/posttraining proficiency [using a live-fire subcaliber firing exercise] was significant on five of six performance measures (Ref 7).

Table 3 (Cont'd)

Skill Acquisition	Skill Retention	Performance Prediction	Transfer of Training
M179 Telfare (Cal .50)	M179 Telfare (Cal .50)	M179 Telfare (Cal .50)	M179 Telfare (Cal .50)
			Final hit performance scores of an M179 Telfare training group on an M1 live-fire test were significantly higher than entry and final scores of an M1 U-COFT training group (Ref 7).
TPGID	TPGID	TPGID	TPGID
Tank crews who trained with a prototype TPGID on TT VI and VII performed [scored] as well on TT VIII as those tank crews who trained with only full caliber main gun ammunition (Ref 29).			The average TT VIII scores of a prototype TPGID trained group [821.26] and a baseline group [840.79] that fired full caliber main gun ammo on TT VI and TT VII were statistically equivalent. At an 80% confidence level there was no statistical difference between the two comparison groups (Ref 29).
The prototype TPGID failed to meet a criterion of having 75% of participants determine that sensory cues for training (except for tracer indication) were satisfactory (Ref 29)			
The average response rating of prototype TPGID as a training device by test participants was "less than satisfactory" (Ref 29).			

Table 4

Summary of Major Findings on Laser Gunnery Training Devices

Skill Acquisition	Skill Retention	Performance Prediction	Transfer of Training
MILES-TSV MILES-TSV simulated main gun firing but not in a precision mode. Negative training occurred because the wide laser beam allowed the gunner to destroy a target even though he may not have had a proper reticle lay on the target. Loader interaction was limited. After-action review provided by the TSV is an extremely effective training and critiquing capability tool (Ref 28).	MILES-TSV	MILES-TSV	MILES-TSV The MILES-TSV trained company fired TT VIII as well as the live-fire trained company (Ref 28).
M55 Laser The M55 Laser was as effective as the TGMTS and Cal .22 device in providing initial gunnery training of M60A3 gunner trainees (Ref 31).	M55 Laser	M55 Laser	M55 Laser The ability of M60A3 gunners to track and hit moving targets using the M55 Laser related positively and significantly to accuracy scores achieved on TT VIII (Ref 20).
3A1028 Laser The unidirectional lead built-in to the 3A1028 Laser can result ... negative training transfer (Ref 30).	3A1028 Laser	3A1028 Laser	3A1028 Laser M60A1 trainees who trained to a 70% criterion level with the 3A1028 Laser or 7.62mm Coaxial Machine Gun [single shot] were significantly more accurate on a live-fire transfer test than a control group which received no simulated fire training. Differences were attributed to amount of training rather than kind [device] of training (Ref 30).

Summary

Standalone Devices. As shown in Table 1, ample evidence supports the conclusion that each standalone gunnery device is effective in terms of skill acquisition. That is, gunnery skills trained on these devices are learned and these skills improve with repeated practice. As to how these device-learned skills are retained, skill retention data exist on only two of the five devices; i.e., the M1 U-COFT and VIGS. For the U-COFT, there is evidence which shows that crews who reach reticle aim level three or higher on the device performed better on TT VIII after 90-day period than those who did not reach reticle aim level three. As for the VIGS, there is not the same kind or quantity of evidence on skill retention. What has been reported is that VIGS training did not lead to better skill retention scores after 10 weeks, even though the accuracy criterion was relaxed.

In terms of performance prediction there is some evidence on several issues for all but the BOT devices. From the authors' viewpoint, the more important of these are: (a) a reliable U-COFT gunnery proficiency test (UGPT) can be used to predict gunnery performance on all U-COFT measures; (b) a global measure of gunner tracking skill can be used to predict speed and accuracy of gunnery performance on the I-COFT; (c) U-COFT matrix progress and amount of training on the device, although significantly related to TT VIII performance, are insufficient as predictors of TT VIII; (d) high M-COFT pretest scores and advancement in the training matrix can be used to predict the speed and accuracy of posttest performance scores on the GUARDFIST I device; (e) the U-COFT is a good predictor of performance accuracy on the VIGS and vice versa; (f) platoon performance on the PGT improves across trials proportionate to amount of device training received; (g) VIGS is not a good predictor of performance accuracy or speed on TOPGUN and vice versa; and (g) VIGS is not a useful predictor of performance accuracy on the I-COFT.

As for transfer of training, there is evidence to support the conclusions that: (a) COFT training (contingent on crews attaining reticle aim level three or higher) transfers to live-fire performance on TT VIII; (b) COFT training (given sufficient progression in the) can compensate for lower TT VIII scores due to decreased number of main gun rounds fired on preliminary tables; (c) training on the BOT trainers transfers positively to speed in applying BOT in an M60A1 live-fire test; and (d) MK60 training does not transfer to M60A1 live-fire performance. Based on our review, there are no data available which show training transfer from the VIGS, PGT, or TOPGUN devices to live-fire performance. There is some evidence of between-device transfer for the VIGS and TOPGUN (with no superiority for either device), for the VIGS and U-COFT (in terms of accuracy but not speed of performance), and for TOPGUN and U-COFT in terms of performance accuracy on stationary targets. The evidence of between-device transfer from TOPGUN to I-COFT is mixed; i.e., no evidence of transfer in one report and some evidence of transfer for speed of

engagement in another report. The only within-device transfer, using VIGS with a more difficult or easier accuracy criterion, did not lead to better transfer scores when the criterion was relaxed.

Tank-Appended Devices. As shown in Table 2, the findings support the conclusion that GUARDFIST I, TGMTS, and SAAB BT-41 are effective in terms of tank gunnery skill acquisition. The GUARDFIST I, however, has not been shown to be effective in training tank crew gunnery procedures, as measured by average crew cut scores on a live-fire TT VIII. There are no empirical data to support or refute skill retention on any tank-appended gunnery device. The more important findings for performance prediction are: (a) high pretest scores on the GUARDFIST I (or M-COFT) can be used to predict success on the same device which, in turn, can predict posttest scores on the alternative device and (b) TGMTS can be used to reliably and accurately measure M60A3 TC/gunner performance. In terms of training transfer, there is evidence to support positive transfer to live-fire performance for all three tank-appended devices, especially for the SAAB BT-41. Also, for tank crews that receive sufficient GUARDFIST I training on offensive engagements, there is evidence of between-device training transfer to M-COFT in terms of speed of engagement, but not accuracy.

Subcaliber Devices. As shown in Table 3, the findings also support the conclusion that subcaliber devices provide effective training in terms of gunnery skill acquisition. Tank crews who trained with a prototype TPGID on TT VI and VII performed as well on TT VIII as those trained with only full caliber ammunition. As with the tank-appended devices, there is no empirical evidence to support or refute skill retention on any of the subcaliber devices. In terms of performance prediction, the only data found relate to the cal .22 device: (a) opening time and percentage of first round hits were the best predictors of M60A3 TT VIII accuracy measures and (b) opening time and total engagement time were the best predictors of M60A3 TT VIII speed measures. Some evidence of training transfer to live-fire performance was indicated for all subcaliber devices. Additionally, (a) M60A1 gunners who used the mini-tank range and cal .22 ammo were more effective than gunners who used the 7.62mm Coaxial Machine Gun, single shot mode; (b) performance of M60A3 gunners on the mini-tank range (1/60th scale and cal .22) was significantly related to TT VIII measures; (c) final hit scores of M1 crews who used the M179 Telfare device for training were significantly higher on a live-fire test than entry and final hit scores of an M1 U-COFT training group; and (d) the average TT VIII scores of a prototype TPGID group and a baseline group did not differ statistically; i.e., no difference at an 80% confidence level.

Laser Devices. As shown in Table 4, all but the 3A102B laser (due to unidirectional lead) data support the conclusion that laser devices are effective in terms of tank gunnery skill acquisition. Unfortunately, there is no evidence to support skill retention or performance prediction for any of the laser

devices. In terms of training transfer, however, there is some evidence which shows that (a) MILES-TSV device is as effective as live-fire training, as measured by TT VIII, and (b) home station training using the M55 laser (with full scale and 1/20th scale) and mini-tank range is positively related to TT VIII proficiency.

Limitations of Training Device Findings

In reviewing each of the reports annotated in the gunnery training device effectiveness literature, a concerted effort was made to identify potential limitations that could possibly affect misinterpretation of the reported major findings on the training effectiveness of each device. In identifying these potential limitations or problems, our purpose was to ensure that accurate conclusions were reached about the training effectiveness of each gunnery device. It was not our intent to denigrate the specific authors or reports. As psychologists involved in the use and evaluation of tank gunnery devices, we are highly cognizant of the difficult, complex, and unpredictable nature of conducting this type of research. As such, we acknowledge the significant contributions made by the authors. Their efforts, individually and combined, provide a solid foundation on which we can build and expand our knowledge and understanding of gunnery training device effectiveness.

Approach

Eight potential limitations were identified to conduct this review of reported findings on tank gunnery device training effectiveness. Each research limitation is based on the sources of errors in transfer experiments reported by Boldovici and Sabat (1985) and Boldovici (1987). Four reports reviewed (reference 6, 15, 25, and 26) did not include empirical evidence and, as such, were not reviewed. The remaining 35 reports were reviewed to identify problems that could lead to misinterpretations about the training effectiveness of each gunnery device.

Results

The results of this review are presented in Table 5 by the reference number of each report. An "XX" in Table 5 signifies a limitation that may threaten the validity of the findings. The gunnery device(s) used in each report referenced is presented in Table 6. A brief description and summary of the limitations associated with training device effectiveness is presented below.

Small Sample Size. Some research projects that involve a small number of participants and minimal statistical variance result in significant and meaningful results. For example, preliminary data from a small sample (N=8) of tank crews revealed a correlation of .86 between Tank Table VIII performance and the extent of advancement into the GUARDFIST I training matrix (Smith & Hagman, 1993). As the authors noted, however, a greater sample size is needed to support a definitive conclusion. More often

Table 5

Potential Limitation of Reported Findings on Training Device Effectiveness

POTENTIAL LIMITATION	REFERENCE NUMBER																																					TOTAL
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	
SMALL SAMPLE SIZE	XX	XX	XX	XX		ANALYTIC	XX				XX	XX			ANALYTIC		XX	XX		XX	XX			XX	ANALYTIC	ANALYTIC			XX			XX							14/35
SUBJECTS NOT RANDOM OR MATCHED		XX					XX									XX					XX						XX						XX			XX		XX	8/35
GROUPS TREATED DIFFERENTLY							XX	XX									XX		XX	XX		XX	XX	XX				XX	XX										10/35
DEVICE SYSTEM ERRORS			XX		XX									XX								XX						XX	XX	XX				XX	XX	XX			10/35
INSUFFICIENT AMOUNTS OF PRACTICE																																			XX				XX	2/35
CEILING EFFECT													XX					XX		XX																			3/35
FLOOR EFFECT																																XX								1/35
UNRELIABLE PERFORMANCE MEASURES			XX					XX						XX		XX	XX		XX				XX			XX					XX		XX		XX			11/35

Note. XX = Potential limitation that may threaten the validity of the reported findings. The numbers in the "TOTAL" column do not include analytic reports.

Table 6

Gunnery Training Devices Used in Each Report Referenced

Reference	Type of Device(s)
1	Battlesight (TOPGUN)
2	COFT
3	Mini-tank range
4	COFT
5	TOPGUN
6**	COFT
7	COFT, Telfare
8	COFT
9	COFT
10	COFT
11	COFT
12	VIGS
13	COFT, TOPGUN
14	MK60 (VIGS)
15**	COFT
16	COFT
17	COFT, Telfare
18	COFT, TOPGUN
19	PGT (COFT)
20	M55 Laser, Mini Tank Range

Reference	Type of Device(s)
21	COFT, Telfare
22	VIGS
23	GUARDFIST I
24	COFT
25**	COFT, MILES, VIGS
26**	COFT, GUARDFIST I, TOPGUN, VIGS
27	COFT
28	BT-41, MILES/TSV, VIGS
29	TPGID
30	3A1028 laser, M73 Coax
31	TGMTS
32	COFT
33	COFT
34	COFT, GUARDFIST I
35	COFT, TOPGUN, VIGS
36	17-4 series, 3A1028 laser
37	TGMTS
38	COFT
39	COFT, VIGS

Note. COFT = Conduct-of-Fire Trainers; GUARDFIST I = Guard Unit Armory Device Full-Crew Interactive Simulation Trainer - Armor; MILES = Multiple Integrated Laser Engagement System; PGT= Platoon Gunnery Trainer; TGMTS = Tank Gunnery and Missile Tracking System; TPGID = Tank Precision Gunnery Inbore Device; TSV = Thru-Sight Video; VIGS = Videodisk Gunnery Simulator; (**) = Analytic.

than not, studies with small samples lead to conclusions of no difference between groups when a difference may in fact exist. When differences are found, however, they are impressive and may make a difference "down the line."

As shown in Table 5, thirteen training device reports (37%) included a small sample size. Having a small sample size does not render the findings useless, but it does threaten their generalizability and validity (Cook & Campbell, 1979). To avoid concluding that no differences exist when, in fact, differences might be present, a sufficiently large number of subjects should

be included. Power analyses (Cohen, 1988; Morrison, 1990) can be performed to determine a sufficient sample size for detecting effects of a given magnitude.

On the basis of a power analysis of gunnery performance measures, Morrison (1990) concluded that statistical tests comparing company-sized samples (N=14) are relatively insensitive to differences between means. The results of Morrison's analyses revealed, for example, that to detect statistical differences using 14 crews, in 8 out of 10 cases, actual mean differences must differ by about two seconds in opening time, 12 percent in hit probability, and over 100 points in Table VIII score. The likelihood of finding these extreme differences in M1 gunnery performance is small given that Hoffman (1989) reported average opening times of 2.1 seconds, average hit probabilities of over 80%, and average Table VIII scores of 845 out of 1000.

Subjects Not Random or Matched. Matching participants on the basis of some pre-existing measure of performance or random assignment to groups often ensures that the groups are "equal" prior to the experimental treatment. If they are not matched or randomly assigned to groups, the differences found between the groups cannot necessarily be attributed to the training device. Most tank gunnery research requires the support of several participants in order to adequately test the device's training effectiveness. This is most easily done by assigning Group A to a training device condition and Group B to a condition that does not use the training device. Comparison of performance on certain criterion tasks can then lead to conclusions about the device's training effectiveness. If Group A, however, has been shown to perform better than Group B on previous criterion measures of gunnery, one cannot simply conclude that training with the gunnery device enhances performance. If, however, the participants were matched with respect to gunnery skill level and no significant differences in previous performance were found, one could conclude that the training device improved performance. It was found that eight reports (29%) did not randomly assign or match participants to create equal groups, though "groups" were assigned randomly. Matching and random assignment do not always eliminate pre-existing differences. Groups should be reformed if, after groups are created, they differ with respect to the measures of performance. Only after equal groups have been attained should the research continue.

When military participants are included in training device research, several difficulties may be experienced with respect to randomization or matching of participants to equal groups. For example, troops obtained for research may be in the process of training for annual gunnery evaluations. It would be imprudent, in this case, to disrupt the integrity of the established units for research purposes. As such, units may exhibit pre-existing differences in certain measures of performance. If one group is more proficient than another, conclusions about training device effectiveness become more difficult to reach.

Groups Treated Differently. Equal treatment of groups once research begins is just as important as the formation of equal groups by matching or random assignment. This simply means that Group A should not be given more training time or more exposure to training personnel than members of Group B. Ten reports (29%) were found which contained groups who were treated differently. Unequal treatment of groups could result from an event that takes place between the pretest and posttest that affects the groups differently, or from pre-existing differences resulting from different home station gunnery training. If the groups are not treated equally during each phase of the research and insulated from adverse occurrences, differences between the groups cannot be attributed to the training device. Cook and Campbell (1979) refer to this as a "history" effect.

Device System Errors. Device systems errors were identified when any condition (e.g., design flaw, equipment malfunction) prevented or interfered with the successful completion of a gunnery task or tasks. Device system errors are important to document because they can be a factor that contributes to the appearance of substandard performance, when in fact poor performance may not have occurred. Ten reports (29%) that were reviewed contained problems in this area. For example, Rose, Wheaton, Allard, Fingerman, and Boycan (1976) noted that unidirectional lead built into the 3A102B laser device limited the performance of some tank gunnery tasks. Device system errors can also impede the training process and create unintended delays or disturbances. Sigtenhorst and Johnson (1982), for example, reported that the TGMTS overheated at times, interfering with the completion of a task. Device system errors that were found in annotating the reports reviewed were noted as limitations.

Insufficient Amounts of Practice. A pervasive principle of training is that task repetition or practice will improve task performance (Holding, 1965; Wells and Hagman, 1989). When the amount of practice on the training device is minimal, however, the likelihood of reaching an established criterion level is lessened. As a result, no difference may be found between groups because of insufficient amounts of practice. Two reports (3%) were found that may have contained this problem. Turnage and Bliss (1990), for example, noted that they attempted to provide enough practice to affect proficiency. They reported, however, that performances on VIGS were still improving at Trial 4, which suggests that continued practice may have resulted in continued improvement. Witmer (1988) also noted that the number of U-COFT and VIGS practice trials may not have been sufficient for the participants to acquire the necessary skills to exhibit inter-device transfer.

Ceiling Effects. A ceiling effect occurs when groups demonstrate such high proficiency on a task that higher levels of performance on that task cannot occur. Because little measurable variance exists between groups who exhibit high performance, no statistically significant difference is obtained. It is possible, however, for the benefits of overtraining to be gained

if the ceiling effect occurred as a result of additional trials beyond reaching task proficiency. Three reports (8%) reviewed exhibited ceiling effects. For example, Kraemer and Smith (1990) reported that no significant group differences were found because of ceiling effects in some TOPGUN target engagement exercises. Ceiling effects can result when tasks are too easy, when training is highly effective, or when both groups are proficient prior to assessment.

Floor Effects. Floor effects, as opposed to ceiling effects, occur when both groups perform poorly on the same task. These effects can occur as a result of extremely difficult tasks, ineffective training for both groups, or a lack of proficiency on the task. When floor effects occur, demonstration of training device effectiveness becomes increasingly more complicated. Only one report (2%) was found that had a floor effect between groups. Therefore, this is not a real problem for future gunnery device research and evaluation.

Unreliable performance measures. Reliability refers to the consistency of performance on a particular measure. The ideal performance measure should facilitate an accurate assessment of the variable under examination every time. For example, a scale should discriminate between heavy and light objects by providing an accurate weight for each object. Likewise, to be considered reliable, a gunnery device should provide consistent measures of gunnery performance. As presented in Table 5, 11 reports (31%) contained potentially unreliable assessments of performance. Turnage and Bliss (1990), for example, found that performance on VIGS could not be used to predict performance on TOPGUN and vice versa. They attributed this finding to a lack of reliable performance measures.

In an example of reliability testing, Graham (1986) examined the reliability of nine U-COFT gunnery measures. He found that six of the measures were reliable indexes of gunnery (Target ID time, Reticle Aim Score, Hit Rate, Target Acquisition Score, First Round Hit Rate, Opening Time), while three measures were not (Azimuth Error, System Management Score, Elevation Error). Criteria for reliability consisted of the Pearson correlation coefficient. Measures with reliabilities greater than .70 were considered dependable. He also found that gunners' hit rates were strongly influenced by the tank commander's performance.

A variety of additional testing conditions can influence the reliability of gunnery performance measures. For example, the driver may have an affect on the gunner's performance when the tank is fired while moving. Similarly, random irrelevancies in the experimental setting (e.g., weather, crew turbulence) may adversely affect gunnery scores. Live-fire performance measures, as such, can be unreliable due to measurement difficulties and the variable nature of the firing tasks (Hoffman, 1989). Failure to consider the types of gunnery performance measures used and their subsequent reliability may result in imprecise results and conclusions concerning training device effectiveness.

Summary

As discussed, eight potential limitations of military weapon systems research, identified by Boldovici and Sabat (1985) and Boldovici (1987), served as criteria for assessing the findings from the 35 reports which included empirical data. For the most part, the findings were replete with limitations--some being more critical than others. As shown in Table 5, the most prevalent limitation was inadequate sample sizes. Over one-third of the reports reviewed had small sample sizes. This is normally due to resource constraints and is likely to continue to be a problem in future device research and evaluation. Methods for determining adequate sample sizes were cited (Cohen, 1988), but these methods will only help when unlimited number of subjects are possible.

Additional limitations which occurred less frequently, but remained equally pertinent to the demonstration of tank gunnery effectiveness, involved groups being treated differently, device system errors, unreliable performance measures, and failure to create equal groups. Only a few reports experienced problems with insufficient amounts of practice and ceiling/floor effects. Cook and Campbell (1979) identify over 20 threats to the validity of research findings which persons who anticipate performing this type of research should be cognizant. Together these reports show that progress has been made toward understanding the role of tank gunnery devices in training gunnery performance. Future research should take extra steps to avoid these limitations.

Discussion/Conclusions

It might appear, based on the sharp highlighting in this report of shortcomings of some research and evaluation efforts, that little has been learned about the training effectiveness of tank gunnery devices. This is not the case. There have been some significant findings, and some products that constitute a considerable contribution to research and development in the training device effectiveness arena. Indeed some positive conclusions can be drawn from what is considered a sparse and sometimes marginal literature.

Major Conclusions

The major conclusions reached by the authors are summarized in Table 7. Except for the 3A102B laser, there is strong evidence to conclude that tank gunnery skills are learned on the training devices. Except for some evidence of skill retention on the COFT and PGT, there is no evidence to conclude that gunnery skills are retained on the other devices. As to performance prediction, it can be concluded that most of the stand-alone and tank-appended devices provide this capability while no such evidence is apparent for the subcaliber (except cal .22) and laser devices. As to training transfer (device to live-fire), some evidence exists for all devices except for three stand-alone devices (PGT, VIGS, and TOPGUN), and the 3A102B laser device.

Table 7

Summary of Major Conclusions From Reviewed References

			SKILL ACQUISITION	SKILL RETENTION	PERFORMANCE PREDICTION	TRANSFER OF TRAINING
DEVICES	STAND ALONE	COFT	●	◑	◑	◑
		PGT	●	◑	◑	○
		VIGS	●	○	◑	○
		TOPGUN	●	○	◑	○
		BOT	●	○	○	◑
	TANK APPENDED	GUARDFIST I	◑	○	◑	◑
		TGMTS	●	○	◑	◑
		SAAB BT-41	●	○	○	◑
	SUBCALIBER	CAL .22	●	○	◑	◑
		7.62 MM	●	○	○	◑
		TELFARE	●	○	○	◑
		TPGID	◑	○	○	◑
	LASER	MILES-TSV	●	○	○	◑
		MS5	●	○	○	◑
		3A102B	○	○	○	○

Note. ● = Strong evidence; ◑ = Some evidence; ○ = No evidence.

Future Requirements

This review and annotated bibliography of the literature on tank gunnery devices identifies what the authors have been able to surmise about device training effectiveness in terms of skill acquisition, skill retention, performance prediction, and training transfer. Future requirements which become immediately apparent as a result of this review can be categorized into three major areas. First, there needs to be research and evaluation conducted in those areas of device training effectiveness where very little or no empirical evidence now exists (e.g., there is no skill retention data on any of the tank-appended, subcaliber, or laser devices reviewed). Second, there needs to be similar efforts conducted (without research limitations) to provide empirical evidence on the training effectiveness of armor gunnery training devices expected to be fielded in the near future; e.g., Precision Range Integrated Maneuver Exercise (PRIME), and Tank Weapons Gunnery Simulation System (TWGSS). Third, there needs to be a review and annotated bibliography of the training device literature on armor devices developed for tactical or maneuver training; e.g., Simulation Networking (SIMNET), Close Combat Tactical Trainer (CCTT), and the Service School Seminar Trainer (JANUS-A).

The results provided by these efforts would provide the U.S. Army Armor School (USAARMS) with valuable data that could be used in the further development of the Armor portion of the Combined Arms Training Strategy (CATS). As such, it would help meet the TRADOC goal of increased training effectiveness and reduced training costs by the integration of training aids, devices, simulators, and simulations (TADDS) into institutional and unit training.

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Smith, M. D., & Hagman, J. D. (1993). Interdevice transfer of training between the Guard Unit Armory Device, Full-Crew Interactive Simulation Trainer - Armor and the Mobile Conduct-of-Fire Trainer (ARI Research Report 1635). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A263 370)

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

Appendix A

Annotated Reviews of Armor Gunnery Training Device Reports

Thirty-nine documents relating to armor gunnery training devices were reviewed and annotated. The abstract format was modeled after the format developed by Ayers, Hays, and Heinicke.[1] The documents are presented in alphabetical order and numbered to correspond with the list of references provided at the end of the appendix. Each reference contains the author(s), year of the publication, title, publishing data, and AD number assigned and controlled by the Defense Technical Information Center (DTIC). Most documents included in this report can be obtained from DTIC--located in Cameron Station, Alexandria, VA: 22304-6145 or from the National Technical Information Service (NTIS)--located at 5285 Port Royal Road, Springfield, VA: 22161.

Explanation of Abstract Format

Each document was condensed into an annotated abstract using a six-point outline as described below. Non-empirical documents (e.g., literature reviews, theoretical reports) were summarized using the same six points, but omitted sub-points in the approach pertaining to empirical matters (e.g., research participants, methods, measures, setting, etc.).

1. Topic Keywords: The topic keywords identify the main subject terms in the document. When available, these terms were obtained from the documents' report documentation page.

2. Short Summary: The short summary describes the problem under investigation, participants, method, major findings, and conclusions.

3. Performing Organization: The performing organization refers to the agency that sponsored the project.

4. Approach: The approach contains specific information about the participants, design, methods, performance measures, and setting (e.g., institutional, field).

   a. Number of Groups: The number of groups into which the participants were divided and assigned for investigation.

   b. Description of Group(s): The description of the groups involved provides details about the assignment of crews or units to specific gunnery training devices or training methods.

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[1] Ayres, A., Hays, R. T., & Heinicke, M. (1984). An annotated bibliography of abstracts on the use of simulators in technical training (Research Product 84-21). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A156 792)

c. Tests or Trials: The tests or trials explained the timing, training sequence, and tasks used in the investigation.

d. Number of Different Types of Measures Used: The number of different measures of tank gunnery collected and reported in the investigation.

e. Description of Measures/Ratings: A description of the measure or dependent variables used in the investigation.

f. Experimental Setting/Training Context: The place (e.g., institutional, classroom, hands-on, field, etc.) in which the training and testing occurred.

g. Statistical Methods: The statistical methods refer to data analysis techniques and procedures used to determine the significance of results.

h. Stage of Training: The stage of training in which the participants belonged.

i. Trainee Sophistication: The level of expertise attained by the participants.

j. User Acceptance or Attitude: The acceptance of the tank gunnery training devices by the user. This is omitted when the authors do not specify user acceptance or attitude.

5. Discussion: This section includes major findings, conclusions, limitations, and considerations.

a. Major Findings: The major findings include a detailed summary of the investigation results.

b. Authors' Conclusions: The authors' conclusions provide their interpretive judgements about the findings of the investigation.

c. Limitations: The limitations include specific threats to the validity of the investigation or conditions which preclude conclusive judgements.

d. Considerations: The considerations refer to general details of the scope, reported findings, or implications of the investigation.

6. Related Work: The related work includes a list of references that provide additional information about the topic(s) or device(s) reviewed.

1. Abel, M. H. (1986). Performance of soldiers on the Battlesight tank gunnery video game (ARI Technical Report 710). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A178 446)

1. Topic Keywords: Armor; M60A1 Tank Gunnery; Training Devices; Battlesight; Video Game; Practice Effect; Training effectiveness.

2. Short Summary: This research examined the effectiveness of a video game (Battlesight) for M60A1 tank gunnery training. In the first two experiments, 12 M60A1 crewmen were divided into two groups based on gunnery experience (tank commanders(TCs)/gunners) and inexperience (drivers/loaders). In Experiment 1, the crewmen used the gunner's primary sight (GPS) and a 100% kill zone (KZ). In Experiment 2, they used the secondary sight (M105D telescope) and a 100% KZ. The criterion measures were total hits and total first-round hits. In Experiment 3, accuracy and speed measures were examined under (a) two different game formats (standard--three lives and 60 rounds of ammo; revised--equal distribution of three lives and 60 rounds of ammo into three separate games) and (b) two separate KZs; 100% or 50%. The results of the first two experiments revealed (a) a significant improvement in total hits and total first-round hits over 10 trials, and (b) no significant differences in performance between experienced and inexperienced crewmen. The results of the third experiment revealed (a) less accuracy when the KZ was reduced from 100% to 50%, (b) improved accuracy (percentage of hits and first-round hits) using the revised format, (c) no improvement in accuracy using the standard (100% KZ) format, and (d) improvement in average time to fire for all groups.

3. Performing organization: U.S. Army Research Institute for the Behavioral and Social Sciences, ARI Field Unit - Fort Knox, Fort Knox, KY 40121-5620.

4. Approach: Experimental

a. Number of Groups: Two in Experiment 1 & 2 and four in Experiment 3.

b. Description of Groups:

(1) Experiments 1 & 2:

(a) Group 1: Six experienced M60A1 tank crewmen (TCs and gunners) who used the GPS and a 100% KZ.

(b) Group 2: Six inexperienced M60A1 tank crewmen (drivers and loaders) who used the M105D telescope and a 100% KZ.

(2) Experiment 3:

(a) Group 1: Fifteen M60A1 crewmen who used a revised game format (equal distribution of three lives and 60 rounds of ammo into three separate games with a 100% KZ).

(b) Group 2: Fifteen M60A1 tank crewmen who used the standard game format (three lives and 60 rounds of ammo with a 100% KZ).

(c) Group 3: Same as Group 1 but using a 50% KZ.

(d) Group 4: Same as Group 2 but using a 50% KZ.

c. Tests or Trials:

(1) Experiments 1 & 2: All 12 M60A1 tank crewmen fired 50 rounds of ammunition per trial for 10 trials.

(2) Experiment 3: For Groups 1 and 3, the 30 subjects had one life, 20 rounds, and 21 enemy tanks per trial for three trials. For Groups 2 and 4, the 30 subjects had three lives, 60 rounds, and 61 enemy tanks per trial for three trials.

d. Number of Different Types of Measures Used: 5

e. Description of Measures/Ratings: In the first two experiments, firing accuracy was measured by number of hits and number of first-round hits over trials. In the third experiment, firing accuracy and speed were examined over trials under two different game formats and two different target KZs. Accuracy was measured by the percentage of hits and percentage of first-round hits. Speed was measured by the average time to fire, which was computed by dividing the elapsed game time by the number of rounds of ammo fired.

f. Experimental Setting/Training Context: The research was conducted in an institutional setting using a hands-on training and testing approach. In the first experiment, the device was programmed to provide: (1) immortality (threat tanks could engage but not kill the subject's tank), (2) use of Stage I and the "qualified" Player Experience Level to eliminate individual differences, (3) no bonus ammo as a result of performance, (4) a four-second time delay between firings to simulate reloading, and (5) 100 threat tanks. The automatic slew was disabled to force the subject to search the battlefield and acquire targets using directions issued by the computer-generated fire command. Before training, subjects listened to taped instructions explaining the Battlesight game play. A 15-minute break was provided after the firing of 100 rounds for each of 10 trials. Data collectors were used to tally the number of hits and first-round hits between each break. In the second experiment, the procedures were the same except subjects were allowed to fire 100 practice rounds using the GPS before training using the auxiliary sight. In the third experiment, the procedures were similar but the device was programmed to include mortality and the use of the automatic slew for target acquisition.

g. Statistical Methods: In the first two experiments, a repeated measures analysis of variance (ANOVA) was calculated to determine whether level of experience had any effect on number of

hits or first-round hits. In the third experiment, repeated measures ANOVA was calculated to determine whether performance differed as a function of game format or KZ. In all experiments, trend analysis examined the learning curve across trials.

h. Trainee Sophistication: Experienced and inexperienced

5. Discussion:

a. Major Findings:

(1) In the first two experiments, there was significant improvement across trials in the number of hits and number of first-round hits. No significant differences were found in performance between the experienced and inexperienced groups.

(2) In the third experiment, there was a significant difference in accuracy between the standard kill zone (100%) and reduced kill zone (50%) groups, with the reduced kill zone groups being less accurate overall.

(3) In the third experiment, the firing accuracy of groups that used the revised video game format (Group 1 and 3) improved. No improvement was indicated for the two groups that used the standard game format.

(4) In the third experiment, all groups' average time to fire improved across the three trials.

b. Authors' Conclusions:

(1) The results should not be interpreted as conclusive evidence of the most appropriate video game configuration for ensuring training effectiveness. In the standard game format, subjects may have emphasized speed over accuracy because the massing of lives and ammo lowers the emphasis on speed. On the other hand, the revised game format (distribution of lives and ammo) may have forced equivalent emphasis on speed and accuracy.

(2) The motivational quality of video games is quite evident by their popularity. However, their instructional and training qualities have yet to be ascertained.

c. Limitations:

(1) The lack of significant difference in performance between experienced and inexperienced tank crewmen may have been the result of the small sample size (N=6).

(2) Research conducted with TOPGUN (follow-up device) casts doubts on the validity of the device data. For example, Turnage and Bliss (1990) found that TOPGUN's reticle aim scores were inaccurate and unreliable. Also, Bliss, Lampton, and Boldovici (1992) found that the lead-error scores on TOPGUN using the M105D telescope were inaccurate.

(3) In research by Kraemer and Smith (1990) with TOPGUN, a later version of Battlesight, reduced score variance for some performance measures was produced by ceiling effects found in some engagement exercises. One reason for such ceiling effects was that the 100% kill zone difficulty level was too easy.

d. Considerations: The classic relationship between speed and accuracy is that speed of responding decreases as a function of aiming difficulty (Fitts, 1954). One reason for not finding evidence to support this relationship may have been that, since instructions did not specify an appropriate strategy, individual differences in responding negated finding any tradeoff effect.

6. Related Work:

a. Bliss, J. J., Lampton, D. R., & Boldovici, J. B. (1992). The effects of easy-to-difficulty, difficult-only, and mixed-difficulty practice on performance of simulated gunnery tasks (ARI Technical Report 948). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD 251 866)

b. Fitts, P. M. (1954). The information capacity of the human motor system in controlling the amplitude of movement. Journal of Experimental Psychology, 47, 381-391.

c. Hart, R. J., Hagman, J. D., & Bowne, D. S. (1990). Tank gunnery: transfer of training from TopGun to the Conduct-of-Fire Trainer (ARI Research Report 1560). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A223 165)

d. Kraemer, R. E., & Smith, S. E. (1990). Soldier performance using a part-task gunnery device (TOPGUN) and its effects on Institutional-Conduct of Fire Trainer (I-COFT) proficiency (ARI Research Report 1570). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A227 403)

e. Turnage, J. J., & Bliss, J. P. (1990). An analysis of skill transfer for tank gunnery performance using TOPGUN, VIGS, and I-COFT trainers (ARI Technical Report 916). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A231 156)

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2. Abel, M. H. (1987). Effects of NBC protective equipment and degraded operational mode on tank gunnery performance (ARI Technical Report 764). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A191 233)

1. Topic Keywords: Armor; M1 Tank; Tank Gunnery; Simulators; U-COFT; Degraded Mode Gunnery; MOPP Gear; NBC Equipment.

2. Short Summary: This research examined performance on the M1 Unit-Conduct of Fire Trainer (U-COFT) by gunners wearing Mission Oriented Protective Posture (MOPP) gear, in normal and emergency operational mode conditions. In Experiment I, the subjects were assigned randomly to one of four groups using a combination of MOPP gear and operational modes. Subjects completed six U-COFT exercises under the conditions corresponding to their assigned group. In Experiment II, a similar group of subjects that had performed four U-COFT exercises under emergency operational mode but without MOPP gear (Witmer, 1988) was combined with Experiment I groups to assess interaction between MOPP gear and operational mode. In both experiments, a pretest was performed without MOPP gear and in normal operational mode for use as a covariate on experimental test performance. Results of Experiment I indicated that the combination of MOPP gear and emergency operational mode degraded firing time, percent hits, and aiming error, especially in long-range engagements. MOPP gear under normal operational conditions degraded aiming error only. Experiment II results revealed degradation on all performance measures by emergency mode. No performance decrements were found for MOPP gear, which did not further degrade performance under emergency mode. Degradation in firing time and aiming error caused by emergency mode was evident in long-range engagements. Multiple correlations between firing time and experience variables were significant, particularly overall time as a gunner.

3. Performing Organization: U.S. Army Research Institute for the Behavioral and Social Sciences, Field Unit - Fort Knox, KY 40121-5620.

4. Approach: Experimental

a. Number of Groups: 4

b. Description of Groups:

(1) Experiment I: The subjects were 48 M1 experienced gunners from the M1 New Equipment Training Team (NETT) at the U.S. Army Armor Center, Fort Knox. They averaged 41.4 months of total time in military, 41.5 months in armor, 17.6 months as gunners, and 61.4 hours of U-COFT time. The subjects were assigned randomly to one of four experimental groups: (a) Group 1--no MOPP, normal operational mode; (b) Group 2--mask only, normal operational mode; (c) Group 3--mask and gloves, normal operational mode; and (d) Group 4--mask and gloves, emergency operational mode.

(2) Experiment II: The subjects were 12 experienced M1 gunners from the NETT who participated as a group in a previous research project (Witmer, 1988) and were used to form another sample of subjects. These 12 NCOs averaged 32.2 months of total time in the miliary, 32.8 months in armor, 17.4 months as gunners, and 40.3 hours of U-COFT time. The four experimental groups were: (a) Group 1--No MOPP, normal mode (from Experiment I); (b) Group 2--No MOPP, emergency mode (from Witmer's project);

(c) Group 3--MOPP, mask and gloves, normal mode (from Experiment I); and (d) Group 4--MOPP, mask and gloves, emergency mode (from Experiment I).

c. Tests or Trials:

(1) Experiment I: The test consisted of six U-COFT exercises comprising 60 single-target engagements using the main gun with day unlimited visibility. All subjects completed the test in two sessions of three exercises each with a 10-minute break between sessions to control for fatigue. The gunner could only fire one round per engagement, had 20 seconds after full target exposure to kill the target before the engagement was computer terminated, and could be exposed (hull down position) for 15 seconds before the computer simulated its destruction. The test exercises were selected on the basis of target range (short and long), and own tank and target movement (stationary-stationary, stationary-moving, moving-stationary, moving-moving). The combination of two ranges with four movement conditions yielded six engagement types. The six test exercises were counterbalanced within each group. This procedure enabled the evaluation of practice effects across test trials.

(2) Experiment II: The test consisted of four U-COFT exercises taken from an earlier project (Witmer, 1988) which were the same as those in Experiment I. The test was performed under the same configuration as in Experiment I but without MOPP gear.

d. Number of Different Types of Measures Used: 2

e. Description of Measures/Ratings:

(1) U-COFT Gunnery Performance Data: Measures of gunner performance extracted from the U-COFT printouts included: (1) average firing time, the elapsed time in seconds from full target exposure to when the gunner fired; (2) number of target hits; (3) number of targets presented; (4) average azimuth aiming error in mils; and (5) average elevation aiming error in mils. The hit percentage for each exercise was calculated by dividing the number of target hits by the number of targets presented. Aiming error was computed as the root mean square (RMS) of azimuth and elevation error (Smith & Graham, 1987); i.e., RMS equals square root of azimuth error squared plus elevation error squared.

(2) Soldier-based Predictor Variables: The following variables from the biographical questionnaire were included in the analyses as measures of experience and ability: (1) total time in military, (2) total time in Armor, (3) total time as a gunner, (4) self-reported General Technical (GT) score from the Armed Service Vocational Aptitude Battery (ASVAB), and (5) number of hours of experience on the U-COFT. GT is composed of both verbal and arithmetic reasoning components, and considered roughly equivalent to intelligence test scores.

f. Experimental Setting/Training Context: The research was

conducted in an institutional setting using a hands-on training and testing approach. For Experiment I, four M1 tank commanders (TCs) from the NETT assisted in testing gunner performance. When the subjects arrived at the test site, specific instructions were read explaining the nature of the testing procedures and the U-COFT. Because of the wide range of U-COFT experience, a pretest of 20 engagements representing different types of exercises used in the experimental conditions was administered. For the pretest the subjects were not in MOPP gear and performed under normal operational mode. On completion, subjects were given a 10-minute break during which they completed a biographical questionnaire. After the break, subjects donned the appropriate MOPP gear and completed six test exercises in two sessions of three exercises. For Experiment II, the experimental setting/training context was the same except that surrogate TCs were used and the gunners were given a U-COFT warm-up/familiarization using 30 test-related engagements.

g. Statistical Methods: Multivariate analysis of variance (MANOVA) on repeated measures was used with post hoc comparisons on all significant main effects and interactions. A one-way MANOVA was performed on pretest performance measures to assess possible group differences in initial performance. MANOVA on repeated measures with constant covariates was used to determine if significant group differences existed on experimental test performance. Pearson product moment correlations were obtained between performance measures and the biographical variables. Average performance measures across exercises in the experimental conditions were used in the correlational analyses. Multiple correlations between the performance measures and biographical variables were obtained from multiple regression analyses using a hierarchial forced entry procedure (Cohen & Cohen, 1983). The experience measures of time in military, time in Armor, time as gunner, and hours of U-COFT were entered into the regression equation as a functional set of variables. Because the sample included subjects with a great amount of experience, the set of experience variables was always entered first into the equation and the GT score was entered last.

h. Use of Instructional Features: Standardized procedures were followed throughout testing to ensure each gunner had an equal opportunity to identify and engage targets. The TCs were trained to issue standardized fire commands, lay the reticle on a predetermined landmark for each engagement, and read instructions verbatim to the subjects. The I/Os were trained to identify the exercise to the TC and gunner, give instructions explaining the exercise, direct TCs to the landmark before target appearance, punch in the gunner's target identification response, perform all driver related functions during each engagement, and print out all measures and call up the next exercise on the U-COFT.

5. Discussion:

a. Major Findings:

(1) Experiment I:

(a) A significant group effect was found for aiming error on pretest performance. Firing time, percent hits, and aiming error were intercorrelated; therefore, all three pretest performance measures were subsequently used as covariates in the analyses of experimental test performance.

(b) A significant overall group main effect was found for each performance measure. Post hoc comparisons between groups revealed a significant effect (lower performance) for Group 4 (mask and gloves, emergency mode) on each measure. The only significant effect for the groups in MOPP gear under normal operational mode (Group 2, Group 3) was on aiming error.

(c) A significant exercise main effect was found for each performance measure. Post hoc comparisons between the exercises revealed a significant effect (lower performance) for long-range targets on firing time and percent hits in all groups.

(d) A significant interaction between group and exercise was found for each performance measure. The post hoc comparisons revealed a significant interaction between Group 4 (mask and gloves, emergency mode) and exercise on each measure.

(e) A positive and stronger relationship was found between firing time and biographical variables then with all other performance measures; seven of the ten correlations were significant.

(f) The multiple regression analyses revealed a significant multiple correlation between gunner firing time and the set of experience variables, particularly overall time as a gunner. This result also was found for aiming error in the experimental conditions.

(2) Experiment II:

(a) No significant differences were found on any performance measure. Therefore, no covariates were used in the analyses on experimental test procedures.

(b) A significant overall group main effect was found for each performance measure. Emergency mode significantly degraded firing time, percent hits, and aiming error. The significant effect for MOPP gear on aiming error found in Experiment I was not replicated. Furthermore, there was no significant interactions between MOPP gear and operational mode.

(c) A significant exercise main effect was found for each performance measure. Planned comparisons between the exercises on target range revealed a significant effect (lower performance) for long-range targets on each performance measure. These findings support the findings of Experiment I.

(d) The interaction between MOPP and exercise was not significant for any performance measure. The interaction between operational mode and exercise was significant for firing time and aiming error. The post hoc comparisons revealed a significant slower firing time in the long-range target exercises under emergency mode conditions. These findings support the findings of Experiment I.

(e) A positive and strong relationship was found between firing time and biographical variables then with all other performance measures; five of the ten correlations were significant. This finding supports the finding of Experiment I.

(f) The multiple regression analyses revealed a significant multiple correlation between gunner firing time and the set of experience variables, particularly overall time as a gunner, while the accuracy measures of percent hits and aiming error were not significantly correlated with experience.

b. Authors' Conclusions:

(1) The results indicated no substantial deficiencies in gunnery performance associated with protective mask and gloves (i.e., did not support previous findings of large performance decrements associated with NBC equipment). Also, wearing MOPP gear did not additionally affect nor further degrade performance under emergency operational mode conditions as might be expected.

(2) Performing under emergency operational mode remained e only significant effect on gunner performance (e.g., degraded iring time and aiming error in long-range target engagements), ut cannot be assumed for all types of target engagement.

(2) The significant correlation found between firing time and time in military suggest that the relationship may be due to the slowing of response times with age, which has been found in other research concerning aging effects on motor behavior.

(3) The significant performance degradation associated with the emergency operational mode strongly suggests the need to develop intensive training countermeasures to moderate the impact of possible battlefield threats on the gunner's proficiency. The U-COFT should be a critical component in such training.

c. Limitations: One factor which may have affected the results of wearing MOPP gear on performance is the experience level of the subjects. As members of the M1 NETT, they were highly qualified and experienced Armor personnel trained to instruct M1 gunnery and conduct of fire procedures. Also, as reported by a number of subjects, they had received a large amount of Nuclear, Biological, and Chemical (NBC) training in MOPP gear.

d. Considerations:

(1) A major problem in research has been the frequent use of samples that are too small in relation to the variability of performance (N = 12 per group), so that the statistical power to detect differences has been inadequate.

(2) The results of power tests to estimate the minimally sufficient number of subjects required to demonstrate effects that may in fact exist were not reported.

6. Related Work:

a. Department of the Army (1985). Tank combat tables M1 (Field Manual 17-12-1). Washington, DC: Author.

b. General Electric (1985). Instructor's utilization handbook for the M1 Unit-Conduct of Fire Trainer (U-COFT) (Vol.1). Orlando, FL: Naval Training Equipment Center.

c. Smith, E. P., & Graham, S. E. (1987). Validation of psychomotor and perceptual predictors of armor officer M1 gunnery performance (ARI Technical Report 766). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD 191 333)

d. Witmer, B. G. (1988). 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 192 246)

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3. Bauer, R. W. (1978). Training transfer from mini-tank range to tank main gun firing (ARI Technical Paper 285). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A178 446)

1. Topic Keywords: Armor; M60A1 Tank Gunnery; Simulation; Mini-Tank Range; Subcaliber Training Devices; Training effectiveness.

2. Short Summary: This research compared the effectiveness of a mini-tank range device with subcaliber training using the tank coaxial machine gun, and assessed transfer of training on main gun Tank Tables (TT) IV, V, and VIII. Two experimental groups of 17 and 15 M60A1 gunners each fired the .22 caliber mini-tank range tables as preliminary exercises to main gun firing. A control group of 18 gunners used the 7.62mm coaxial machine gun (single shot) to fire preliminary tables. The control group and one experimental group fired 130 rounds each on the preliminary tables; the second experimental group fired 260 rounds, the full number prescribed for mini-tank range tables. Independent evaluation teams were used to collect and record live fire

performance measures on main gun TT IV, V, and VIII. The results revealed that the group that fired 260 rounds on the mini-tank range had faster first-round time-to-fire scores on TT IV, achieved the best main gun hit scores on TT IV and VIII, and attained the best overall scores on TT VIII with no crew errors. Differences among the three groups on the main gun performance measures were not statistically significant. Individual gunner experience showed no significant relationship with main gun performance. Overall, gunnery on the mini-tank range exercises was more accurate and efficient, and less costly than on the 7.62mm subcaliber device.

3. Performing organization: U.S. Army Research Institute for the Behavioral and Social Sciences, ARI Field Unit - Fort Knox, Fort Knox, KY 40121-5620.

4. Approach: Experimental

a. Number of Groups: 3

b. Description of Groups: The subjects were 50 M60A1/AOS gunners from three companies in an armored cavalry battalion, who participated in the research during their annual gunnery training and crew qualification. To maintain company integrity during the training (no random assignment of crews), the design involved a comparison among the three company-size groups. Although one of the three groups (Group 2) appeared to have more experience in the Military Occupational Specialty (MOS) 11E (Armor Crewmen) and another group (Group 1) had more experience as tank gunners, the groups were considered equivalent for purposes of research.

c. Tests or Trials:

(1) Group 1: The subjects were 17 tank gunners who each fired 130 rounds of .22 caliber ammunition on preliminary TT I thru VII using the mini-tank range, as described in TC 17-12-6 (U.S. Army Armor School, Field Mini-Tank Range Complex, 1975). They also completed a Tank Crew Qualification Course (TCQC), a ranging and tracking course, and a synchronization and alignment exercise.

(2) Group 2: The subjects were 15 tank gunners who each received the same experimental gunnery training as Group 1, but fired 260 rounds of .22 caliber ammunition on TT I thru VII.

(3) Group 3: The subjects were 18 gunners who each fired 130 rounds of 7.62mm ammunition using the coaxial machine gun (single shot) on preliminary TT I thru III as described in TC 17-12-5 (U.S. Army Armor School, Tank Gunnery Training, 1975). They also completed the TCQC, ranging and tracking course, and synchronization and alignment exercise.

d. Number of Different Types of Measures Used: 4

e. Description of Measures/Ratings: To assess transfer of

training, the criteria were gunnery performance on tank main gun TT IV, V, and VIII, as scored by evaluation teams drawn from resources other than the participating battalion. On TT IV and V, the measures were (1) number of hits, (2) percentage of engagements in which at least one hit was obtained, and (3) time-to-fire the first round (in seconds) on each engagement. On TT VIII, the measures were (1) number of hits, (2) percentage of engagements in which at least one hit was obtained, and (3) total firing time. To ensure group equivalency, the criteria were four experience measures: (1) months of experience in the MOS, (2) months of experience in the tank commander (TC) position, (3) months of experience in the gunner position, and (4) number of gunners who qualified during the prior three years.

f. Experimental Setting/Training Context: esearch was conducted in a field setting using a hands-on tr g and testing approach. A BC scope located in the range tower was used to score TT IV and V main gun hits. A timer mounted on each firing tank was used to record time-to-fire first rounds. To get equivalent times-to-fire, each gunner was instructed to lay the main gun off targets and on a pole marking the edge of the range fan prior to each engagement. Timing began either with movement of the gun or the TC's fire command alert of "Gunner", whichever was observed first. Elapsed time closed with the firing of the main gun. On the 7.62mm range, targets for TT I, II, and III were concentric four-inch and eight-inch circles located at 60 meters. Soldiers in Group 3 (the control group) had difficulty in achieving convergence with the coaxial machine gun at 60 meters versus the designed convergence at 800 meters. Shimming was needed to force the gun to the extreme right of the aperture ring. On the mini-tank range, the nearest targets were located at about 1000 meters simulated by an actual range of 53 feet near the front edge of the sandtable. From that line forward, each foot represented 100 meters. The targets used for TT I and II were slightly smaller in angular area than targets used on the 7.62mm range.

g. Statistical Methods: The data were analyzed using the analyses of variance (ANOVA) technique (Kirk, 1968). Spearman-Brown correlation coefficients were calculated post hoc between level of experience and TT VIII scores to assess equivalency of groups. Descriptive statistics also were used to analyze the experience measures and gunnery data. For comparison purposes, the main gun TT VIII scores were transformed into percentages of the maximum score possible for each gunner on day and night firing combined. Machine-gun scores from preliminary tables were excluded in the statistical comparisons.

h. Stage of Training: Annual tank gunnery density.

6. Discussion:

a. Major Findings:

(1) Groups which trained on the mini-tank range achieved better time scores (time-to-fire first round) than the control group on TT IV but not on TT V. The differences were significant between Groups, Tables, and Groups by Tables interaction.

(2) Group 2 showed the best hit performance on TT IV, but all groups performed equally well on TT V, the moving target table. The differences between the groups, however, were not significant. ANOVA with unweighted means solution showed a significant difference between Tables, but no significant differences among groups and no significant interaction.

(3) Group 2 had the highest mean score (calculated as percent of maximum possible scores) on TT VIII; Group 1 = 67%, Group 2 = 80%, Group 3 = 74%. However, the difference among groups was not significant.

(4) Group 2 average (median) performance on TT VIII was Distinguished (the highest level of qualification), while the other two groups' average performance was Expert. However, the mean score percent difference was not significant.

(5) Differences between groups on percentage of total engagements in which one or more hits were scored favored Group 2 on TT IV and VIII, but the differences were not significant. ANCVA with unweighted means solution was significant for Tables, but not significant for Groups and Groups by Tables interaction.

b. Authors' Conclusions:

(1) In general, gunnery on the mini-tank range exercises was more accurate and efficient, and less costly than the 7.62mm range firing used for comparison.

(2) Use of the mini-tank range exercise in preliminary subcaliber training prior to main gun firing was shown to be at least equally effective to the 7.62mm range in terms of transfer.

(3) Gunners given the full training experience (260 rounds) on TT I thru VII (Group 2) performed well on main gun TT IV and VIII. Cutting these exercises 50% (130 rounds) resulted in relatively poor performance on main gun tables, but the difference was not significant.

(4) Mini-tank range exercises may be further enhanced by better scoring, practice distribution and administration of the exercises with emphasis upon correct crew procedures.

c. Limitations:

(1) There were equipment maintenance and operational problems with both old and new tanks in the battalion. During the research, older M60A1 tanks were exchanged for new M60A1/AOS tanks (with add-on stabilization) throughout the battalion.

(2) Despite the fact that no firing was done "on the move" during the preliminary exercises, the greater number of new M60A1/AOS tanks in Group 2 (14 of 15), as compared to 9 of 17 for Group 1 and 10 of 18 for Group 3, may have contributed to the better performance of Group II on TT VIII.

(3) The control group experienced great difficulty in achieving convergence of the coax machine gun at 60 meters. As a result, most of the three days allotted for TT I, II, and III (nearly 1.5 days) was spent on TT I. This, in turn, reduced the time remaining for the bulk of the preliminary firing tables.

(4) The device evaluation did not address the issue of measurement reliability; no specific testing toward reliability.

(5) In general, the three groups did not fire the same number of main gun rounds on each table, one company did not fire second rounds after first-round hits on TT IV, and gunners who achieved more first-rounds hits on TT VIII used fewer rounds and received more points for rounds saved.

d. Considerations:

(1) Live-fire performance tends to be unreliable because of measurement difficulties and the nature of the firing tasks. Performance on any single engagement is, at best, only a rough indicator of proficiency (Hoffman, 1989).

(2) It is a common practice that crews know or "G-2" the TT VIII course before their qualification run. This knowledge plays a major role in target acquisition, which in turn, results in much faster opening times and increased TT VIII points score.

(3) The TT VIII scores are confounded by not having used the crews' first-run data. Crews that fail to qualify on their first run are retested, normally firing only those engagements that they failed previously. The company commander, however, may require a crew to refire the entire set or subset of engagements.

6. Related Work:

a. Department of the Army (1977). Tank gunnery for M60, M60A1, M60A1(AOS), and M48A5 tanks (FM 17-12-2). Washington, DC: Author.

b. Hoffman, R. G. (1989). Description and prediction of Grafenwoehr M1 Table VIII performance (Technical Report 837). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD B136 331)

c. Kirk, R. E. (1968). Experimental Design: Procedures for the Behavioral Sciences. Belmont, CA: Brooks/Cole.

d. U.S. Army Armor School (1975). Tank Gunnery Training (Training Circular 17-12-5). Fort Knox, KY: Author.

e. U.S. Army Armor School (1975). F. .d Mini-Tank Range Complex (Training Circular 17-12-6). Fort Knox, KY: Author.

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4. 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)

1. Topic Keywords: Armor; M1 Tank; Tank Gunnery; Simulators; U-COFT; Crew Turbulence; Training Effectiveness; Prediction; ASVAB.

2. Short Summary: This research reviewed and evaluated the available data relating performance of U.S. tank crews in the 1985 Canadian Army Trophy (CAT) competition to training and personnel variables. Data were collected from existing company records and interviews with cadre and crews. Training variables included performance on the M1 Unit-Conduct of Fire Trainer (U-COFT) and device mix strategies, while personnel variables included level of crew turbulence, Armed Services Vocational Aptitude Battery (ASVAB) scores, and unit assignment policies. Criterion measures from two training periods on the U-COFT included target identification time, target hit time, number of hits, and number of rounds fired. Biographical data and ASVAB scores were also obtained for all CAT personnel. Correlational analysis were used to examine the relationship between CAT performance and U-COFT, ASVAB, biographical, and crew turbulence data. The results revealed that (a) speed measures from the second U-COFT period were positively correlated with CAT performance, (b) the top-scoring unit received the greatest amount of U-COFT training, (c) no strong relationship was found between ASVAB and CAT performance, (d) the average ASVAB scores for the tank commander (TC) were higher than the gunner's scores in the two higher scoring units and vice versa in the lowest scoring unit, and (e) the level of crew turbulence was highest in the unit with the best CAT performance.

3. Performing Organization: U.S. Army Research Institute for the Behavioral and Social Sciences, Field Unit - Fort Knox, KY 40121-5620.

4. Approach: Analytical

a. Number of Groups: 2

b. Description of Groups: The subjects were TCs and gunners from platoons in three different armor divisions located in the U.S. Army Europe (USAREUR) who were involved in the train-up for the 1985 CAT competition. The first group was composed of 14 TC/gunner pairs that remained intact throughout train-up and the CAT competition. This group's data base contained measures from the first U-COFT training period, the second U-COFT training

period, and the CAT competition. The second group and associated data base consisted of measures from all 24 TC/gunner pairs who participated in the CAT competition.

c. Tests or Trials: U-COFT pre- posttests and CAT results.

d. Number of Different Types of Measures Used: 3.

e. Description of Measures/Ratings:

(1) U-COFT: The U-COFT performance measures were (a) average target identification time, (b) average target hit time, (c) number of hits, and (d) number of rounds of ammunition fired. Percent hits was used as a measure of firing accuracy, and the difference between target hit time and target identification time was used as a measure of engagement speed. All U-COFT data were extracted from U-COFT printouts obtained from the units and the U-COFT manufacturer.

(2) CAT: The CAT performance measures were (a) average opening time, (b) number of hits, (c) number of rounds fired, and (d) average range of targets. Percent hits were computed as a measure of accuracy. CAT performance for each TC/gunner pair was determined after the competition by both the platoon leader and platoon members' reenactment on paper of each battle run. The tank platoon leader's matching of crew with engaged target and the hit/miss data resulted in a crew's CAT performance measure. Copies of the judges' scoresheets were obtained for each tank platoon's battle run with engagement times and target ranges. The platoon leader's matching of crew and engaged target was evaluated against the judge's scoresheet and the range map to determine individual crew engagement times and range to target. Discrepancies were resolved by assuming the official scoresheet was correct in providing target range and that the platoon leader was correct in determining which tank crew engaged the target.

(3) ASVAB: The ASVAB analysis was conducted using TC and gunner scores obtained from the Defense Manpower Data Center, Monterey, CA. The ASVAB is a multiple-choice test containing 10 subtests. Four subtests are combined to form the Armed Forces Qualification Test (AFQT), which is considered a general measure of trainability and the primary criterion for enlistment. Other subtest combinations are used in occupational classification. Three of these, along with AFQT, were used in this analysis. The CO (combat), GM (general mechanical), and ST (skilled technical) composites were used because they address the types of skills needed in tank gunnery.

f. Experimental Setting/Training Context: Each unit's U-COFT training data, computer printouts for each TC/gunner pair, were collected from two training periods. The first training period consisted of standard U-COFT exercises, each containing six-ten engagements. The engagements varied in target range, target movement, type and number of targets, and the movement of the crew's tank. The crewmen received an orientation phase for

familiarization with U-COFT followed by a pretest consisting of six-nine exercises. A posttest was given after seven training sessions that was identical to the pretests. Specially prepared exercises were used in the second training period on the U-COFT. These exercises were based on a visual system which replicated the actual CAT competition range. Again, the U-COFT pre-posttest were separated by seven training sessions. The training sessions consisted of exercises which (as before) also differed in target and tank movement conditions. After the CAT competition, platoon leaders were interviewed for individual crew performance data.

g. Statistical Methods: Descriptive statistics and analysis of variance (ANOVA) were calculated to examine unit differences in U-COFT pre- posttest performance measures for both training periods. Pearson product-moment correlation coefficients were used to evaluate the relationship between each variable (U-COFT, ASVAB, Biographical, Turbulence) and CAT performance.

h. Stage of Training: Highly experienced TC-gunner pairs.

6. Discussion:

a. Major Findings:

(1) For the TC/gunner pairs that remained intact through the competition, performance improvement occurred on all measures from pre- posttest after seven training sessions on the U-COFT. Improvement occurred for all three units and training periods.

(2) Measures of speed from the second training period on U-COFT were positively related to speed in the CAT competition. However, accuracy measures on the pre- and posttests from both training periods were not related to CAT accuracy measures.

(3) The only meaningful difference between the three units on the U-COFT posttests when compared to their performance in the competition was in the speed of engagement.

(4) Only a few correlations between the TC and gunner ASVAB test scores and CAT performance were significant. The TC's ST score was negatively related to accuracy and speed measures, which may have resulted from the emphasis on speed in the CAT competition's scoring system. The gunner's GT, CO, and AFQT test scores were positively related to engagement times, suggesting that the higher the score, the longer the engagement time.

(5) Correlations computed between TC and gunner ASVAB scores and AFQT found three out of the four negative correlations were significant. The negative correlation suggested that the higher the TC scores, the lower gunner scores, and vice versa.

(6) The two units who received more points in the CAT competition had TCs with higher average ASVAB scores and were paired with gunners who had lower average scores. In contrast,

the unit with the lowest points paired TCs who had lower average scores with gunners who had higher average scores.

(7) The TCs time in duty position with the crew was signiiicantly correlated with the accuracy measure.

(8) The gunner's time in pay grade was positively correlated with accuracy; i.e., the longer the time in pay grade, the greater the accuracy.

(9) The unit with the best overall crew stabilization and least turbulence had the lowest scores in the competition. The unit that had the most turbulence had the highest scores.

b. Authors' Conclusions:

(1) Overtraining appears to be critical in performing well under the stressful conditions of the CAT competition.

(2) Mixing device-based training with training on the actual equipment prevents learning device-specific responses and also maintains a high level of motivation.

(3) High-fidelity simulators such as the U-COFT are advantageous as part of a CAT training program and a diagnostic tool in personnel selection.

(4) The results of examining the level of turbulence suggest that commanders of CAT units should not hesitate when making personnel changes to achieve the best crew combination.

c. Limitations:

(1) The basis for the report was the available U-COFT data furnished by the units involved in the CAT competition and the subjective opinions of the participants who were interviewed.

(2) The data base consisting of measures from TC/gunner pairs that remained intact throughout train-up and the CAT competition (N=14) may not meet the statistical requirements for external validity and generalizability of results.

d. Considerations: The assumption that the platoon leader was correct in determining which crew engaged the target may be wrong; this determination was made at some time after CAT. Also, accuracy of measuring specific tank-to-target ranges from a range map to assign hit/miss scores for crews is unknown, as are the number of discrepancies that were resolved using this procedure.

6. Related Work:

a. Scribner, B. L., Smith, D. A., Baldwin, R. H., and Phillips, R. L. (1986). "Are smart tankers better?" Armed Forces and Society, Vol. 12, No. 2, Winter.

b. Wallace, J. R. (1982). The Gideon criterion: The effects of selection criteria on soldier capabilities and battle results (USAREC Research Memorandum 82-1). Fort Sheridan, IL: U.S. Army Recruiting Command.

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5. Bliss, J. P., Lampton, D. R., & Boldovici, J. B. (1992). The effects of easy-to-difficulty, difficult-only, and mixed-difficulty practice on performance of simulated gunnery tasks (ARI Technical Report 948). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A251 866)

1. Topic Keywords: Armor; M1 Tank; Tank Gunnery; Training Devices; TOPGUN; Training Methods; Performance Evaluation; ROTC.

2. Short Summary: This research examined the effects of varying difficulty levels on performance of gunnery tasks. Sixty student subjects were randomly assigned to one of three training groups. Each group of 20 subjects practiced three blocks of 36 trials, which required tracking and shooting moving targets using TOPGUN, under one of three conditions: (a) an easy-to-intermediate-to-difficult progression of targets (PROG), (b) a random order, mixed-difficulty of targets (MIX) or (c) all difficult targets (DIFF). Immediately after training, all three groups were tested on a randomly ordered set of 36 easy, intermediate, and difficult targets. The dependent variables were target hits, time to fire, azimuth error, and aiming error. The results revealed that (a) learning occurred during practice; (b) group differences were not significant for any of the dependent measures; (c) paid Reserve Officer Training Course (ROTC) students achieved significantly greater hit percentages and smaller aiming errors than did non-ROTC students who received extra credit for participation; (d) the PROG group and the MIX group achieved significantly greater hit percentages of easy targets than did the DIFF group; and (e) the PROG group achieved significantly greater hit percentages of difficult targets than did the MIX group.

3. Performing Organization: U.S. Army Research Institute for the Behavioral and Social Sciences, PM TRADE Field Unit, 12350 Research Parkway, Orlando, FL 32826-3276; University of Central Florida (UCF), Institute for Simulation and Training (IST), P.O. Box 25000, Orlando, FL 32816.

4. Approach: Experimental

a. Number of Groups: 3

b. Description of Groups: Subjects were 20 undergraduate students attending psychology classes at UCF. Ten students were from ROTC units who received no extra course credit, but were paid $5.00 per hour for participating, and 10 were non-ROTC students who were given extra course credits for participating.

c. Tests or Trials:

(1) Subjects in PROG Group: The 20 subjects received TOPGUN familiarization, three 36-trial blocks (easy-intermediate-difficult), and a 36-trial randomly ordered test block.

(2) Subjects in DIFF Group: Same as above except the subjects received three 36-trial blocks of difficult targets.

(3) Subjects in MIX Group: Same as above except the subjects received three 36-trial training blocks of mixed (nine easy, 18 intermediate, nine difficult) targets.

(4) All Groups: All subjects reported for about one and one-half hours of training and testing. Each completed a consent form and a background questionnaire on age, grade level, amount of video-game experience, and avowed normal color vision.

d. Number of Different Types of Measures Used: 3

e. Description of Measures/Ratings: The single measure of gunnery speed was time-to-fire, in seconds. The two measures of gunnery accuracy were point-of-impact scores (azimuth error and elevation error), and hit percentages. The timing for the time-to-fire measure began when automatic slewing of the Gunner's Auxiliary Sight (GAS) stopped and ended when the firing button was pressed. Point-of-impact score was calculated as a round's vertical and horizontal displacement in milliradians from the center of target mass at the time of the round's impact. Hit percentage was calculated as the number of hits divided by 36, the number of rounds fired in each training and test block.

f. Experimental Setting/Training Context: The research was conducted in an institutional setting (a trailer housing TOPGUN) using a hands-on training and testing approach with standardized instructions. A single experimenter conducted both training and testing. Device familiarization included general information about TOPGUN, how to manipulate the gunner controls, and how to use the GAS to engage targets. The experimenter instructed each student to fire only one round at single targets presented during training. After familiarization, the students practiced three 36-trial training blocks, the last of which was followed by a 36-trial randomly ordered test block. Each training and testing block lasted about 12 minutes with 5-minute rest periods between blocks. The TOPGUN exercises of various difficulty were devised by programming variations in target speeds and ranges. 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 and far ranges and slow speeds comprised the intermediate difficulty exercises. The nine combinations of far ranges and fast speeds constituted the difficult exercises. The research required four different sets of 36 exercises. The sequence of range-speed combinations were randomized within and across each exercise set. Each exercise contained only one target visible for five seconds, with 5-sec intervals between exercises. The exercises did not contain terrain features which would have hidden the targets, and color

differences between targets and terrain made all targets easy to detect. Target range for each exercise was presented on the right of the TOPGUN display, unaccompanied by TOPGUN's optional announcement of range. Performance feedback provided by TOPGUN included visual representations of hits and misses and device summary performance measures i.e., total time spent practicing, number of rounds fired, mean times and rounds used to destroy targets, and total number of targets destroyed. The experimenter gave corrective feedback to address various gunnery errors, using a standardized script. Students were not given information about how their scores compared to the scores of other students.

g. Statistical Methods: Data were analyzed using t-tests comparing Block 1 and Block 3 scores to determine if learning occurred as a function of treatments. Analyses of variance (ANOVA) techniques were calculated to determine (1) whether and how scores differed as functions of treatments and of ROTC membership (group x ROTC/non-ROTC) and (2) how hit percentages and firing times differed as functions of treatments and of exercise difficulty (group x difficulty level). A Peritz multiple comparison (Martin and Toothaker, 1989) was calculated to determine between which groups differences occurred in cases where group x difficulty-level interactions were significant.

h. Trainee Sophistication: Novice

5. Discussion:

a. Major Findings

(1) The trial effects on TOPGUN showed that the hit percentages for the MIX and DIFF groups increased across training blocks while mean time to fire, mean elevation error, and mean azimuth error decreased. For the PROG group, the hit percentage declined and time to fire increased. For the Block 4 test, hit percentages were greater than those of Block 3 for all groups.

(2) The t-test results showed learning occurred with practice. Mean scores for all measures were significant for the MIX and DIFF groups, with all differences in the right direction.

(3) The ANOVA results revealed no significant difference between the three groups on any dependent measure. Significant differences were found between ROTC and non-ROTC students' hit percentages, azimuth error, and elevation error, with differences favoring the ROTC students. None of the interactions between group assignment and ROTC membership was significant.

(4) The ANOVA summaries showed no significant difference as a function of group assignment on Block 4 (test) times to fire and hit percentages, but significant differences as a function of difficulty level. A significant group by exercise-difficulty interaction was found for hit percentage, but not firing time.

(5) The Peritz multiple comparisons showed that three of the nine possible comparisons were significant, suggesting that learning the discriminations required for applying target lead allowed the MIX and PROG groups to hit a greater percentage of the easy targets than the DIFF group. Also, for unknown reasons, the PROG group achieved a significantly greater hit percentage than either the MIX or DIFF group on the difficult exercises in the Block 4 test.

b. Authors' Conclusions:

(1) Practice should vary along the dimensions and range of values over which transfer conditions are expected to vary. This seems especially germane to training for situations for which less than complete knowledge about the characteristics of target arrays that will be encountered in combat is available.

(2) 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.

d. Limitations:

(1) About one-fourth of the azimuth and elevation scores from the training blocks were not available for analysis because of problems in TOPGUN's data-recording software.

(2) The 36-trial test block was not sufficiently long enough to detect differences.

(3) Practice using easy and intermediate difficulty targets by the DIFF group had interfering performance effects.

(4) Training effects were not measured at various intervals after training to account for likely changes in the direction and slope of training and generalization functions across time.

(5) Measures of transfer and retention were not used as dependent measures along with end-of-training test scores.

d. Considerations:

(1) The adequacy of TOPGUN to accurately and reliably measure tank gunnery performance is questionable. As reported by Trunage and Bliss (1990), students reported minimal lead being required sometimes even in primary and thermal mode against moving targets, no effect of target hit even though the round is seen as a target hit, and azimuth and elevation errors sometimes being greater when the target is hit than when it is missed.

(2) Students were allowed 10-20 minutes of practice on TOPGUN prior to being trained on the first block of 36 moving engagement exercises. As noted by Kraemer and Smith (1990), the

effects of practice led to increased performance for soldiers in the control group from pre- to posttest, thereby negating the chances of finding significant differences between control and experimental training groups.

(3) The kill zone used with TOPGUN to produce a hit was too low; i.e., 100% of the target box. As noted by Kraemer and Smith (1990), ceiling effects found with some TOPGUN exercises resulted in reduced score variance in some of the performance measures. One reason for such ceiling effects was the 100% kill zone. As their test data indicated, nearly 80% of the targets attempted were hit. As shown in research conducted by Hart, Hagman, and Bowne (1990), who also used a 100% kill zone, the mean accuracy score after just 10 stationary engagements using the GAS was over 90% for close targets and over 80% for distant targets.

(4) Novice gunners are trained to apply a standard 2 1/2 mil lead when firing their first armor-piercing discarding sabot-tracer round (APDS-T) against moving targets using the GAS. The reason is that hitting moving targets with the GAS is difficult due to the complexity of the cognitive skills; i.e., the gunner must mentally calculate the appropriate azimuth and elevation values needed to establish a correct aiming point given the combination of target characteristics such as size, speed, range, and direction.

6. Related Work:

a. Hart, R. J., Hagman, J. D., & Bowne, D. S. (1990). Tank gunnery: transfer of training from TopGun to the Conduct-of-Fire Trainer (ARI Research Report 1560). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD-A223 165)

b. Kraemer, R. E., & Smith, S. E. (1990). Soldier performance using a part-task gunnery device (TOPGUN) and its effects on Institutional-Conduct of Fire Trainer (I-COFT) proficiency (ARI Research Report 1570). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A254 289)

c. Martin, S. A., & Toothaker, L. E. (1989). PERITZ: A FORTRAN program for performing multiple comparisons of means using the Peritz Q method. Behavior research methods, instruments, & computers, 21, pp 465-472.

d. Turnage, J. J., & Bliss, J. P. (1990). An analysis of skill transfer for tank gunnery performance using TOPGUN, VIGS, and I-COFT trainers (ARI Technical Report 916). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A231 156)

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6. Boldovici, J. A., Bessemer, D. W., & Haggard, D. F. (1985). Review of the M1 Unit-Conduct of Fire Trainer (U-COFT) validation and verification test report (ARI Research Note 85-56). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A173 938)

1. Topic Keywords: M1 Tank; Tank Gunnery; Training Devices; U-COFT; Performance Evaluation; Simulation.

2. Short Summary: This document was developed in response to a request for a review of a report prepared by the General Electric Company (1984), "Training Matrix Validation and Verification Test Report for the M1 Unit-Conduct of Fire Trainers (U-COFT)," which argued for retraining crews on U-COFT about every three to ten weeks. The validation and verification report (V/V) attempted to (a) identify and correct deficiencies in the U-COFT hardware and software, and (b) determine the extent to which practice with U-COFT improved proficiency on the U-COFT. The authors concluded that the results of the V/V were based on inordinately small sample sizes, and that the transition group practiced 33% longer (40 vs. 30 hrs) and performed 20% more exercises (174 vs 143) than the sustainment group. Thus, the V/V findings regarding skill retention were not reliable enough to be used in making decisions about U-COFT retention or retraining intervals.

3. Performing organization: U.S. Army Research Institute for the Behavioral and Social Sciences, ARI Field Unit - Fort Knox, Fort Knox, KY 40121-5620.

4. Approach: Analytical

5. Discussion:

a. Major Findings:

(1) U-COFT hardware and software improvements resulting from the V/V report were useful.

(2) Thirty hours of U-COFT sustainment training resulted in considerable average gains in the proficiency of a test group (five TC-gunner pairs).

(3) Forty hours of U-COFT transition training with a different group of five TC-gunner pairs resulted in average exit-level scores greater than or equal to those of the sustainment group. Proficiency gains for the transition group, because of unobtainable scores, could not be estimated.

(4) Proficiency gains in U-COFT target-acquisition were underestimated by at least one-third in the V/V report.

(5) U-COFT training produced substantial improvement in acquisition time, engagement time, and first round hits for both the sustainment and transition groups.

(6) Nine hours of U-COFT training and testing led to significant improvements between pre-posttest scores of eight Canadian Armor Trophy (CAT) TC-gunner pairs (no measures mentioned).

(7) The results of the V/V were based on inordinately small sample sizes, and that the transition group practiced 33% longer (40 vs. 30 hrs) and performed 20% more exercises (174 vs 143) than the sustainment group.

(8) The V/V results concerning proficiency retention were not reliable enough to warrant decisions about retention or retraining intervals on the U-COFT.

6. Related Work:

a. General Electric Company (1984). Training matrix validation and verification test report for the M1 Unit-Conduct of Fire Trainers (U-COFT). Author.

b. General Electric Company (1985). Instructor's utilization handbook for the M1 Unit-Conduct of Fire Trainer (U-COFT) Volume 1: General Information. Daytona Beach, FL: Author.

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7. Butler, W. G., Reynolds, M. J., Kroh, M. Z., & Thorne, H. W. (1982). Training developments study--M1 (Abrams) Tank Unit-Conduct of Fire Trainer (TRASANA TEA-11-82). White Sands Missile Range, NM: U.S. Army TRADOC System Analysis Activity. (AD B954 521)

1. Topic Keywords: M1 Tank; Tank Gunnery Training; Training Devices; UCOFT; M179 Telfare; Performance Evaluation; Training Effectiveness; Training Transfer Effectiveness; Training Transfer

2. Short Summary: Tank crew performance was evaluated under two M1 approaches. The first involved the use of a contractor-developed, proponent-reviewed, Unit-Conduct of Fire Trainer (U-COFT) training program. The second consisted of a proponent-developed baseline training program using the M179 Telfare subcaliber device mounted on the M1. The results revealed that (a) both programs exhibited effective training transfer; (b) the baseline provided greater training transfer effectiveness, but the difference was not statistically significant); (c) U-COFT training sustained device performance for the percentage of first round hits, average time to fire first round, and the average time to acquire the first target; and (d) final hit performance scores of the baseline group on a subsequent Battlefield Firing Diagnostic (BFD) test were significantly higher than entry and final scores of the U-COFT trained group.

3. Performing Organization: TRADOC Systems Analysis Activity, White Sands Missile Range, NM 88002.

4. Approach: Experimental

a. Number of Groups: 2

b. Description of Groups: The test group consisted of three tank companies from one M1 battalion which had recently completed M1 training as part of the M1 Operational Test (OT) III.

(1) U-COFT Group: This group consisted of two tank companies selected to train on the U-COFT (22 tank commander [TC]/gunner pairs). The TC/gunner pairs in this group spent 6.3 hours per crew on U-COFT and did not participate in any other M1 gunnery training when they were not training on the U-COFT.

(2) Baseline Group: This group consisted of one tank company (eight four-man crews) selected by the proponent to train exclusively on the M1 tank using the M179 Telfare device. This group spent 6.75 hours per crew in training. Data obtained on the M1 tank were referred to as baseline data.

c. Tests or Trials: This test was conducted in three phases at Fort Hood, TX, from July-September, 1981.

(1) Phase I: In this phase, TC's and gunners from both training groups were administered a pretraining examination. The examination was composed of a TRADOC developed Battlefield Firing Diagnostic (BFD) test, a vehicle recognition test, and a tracking test. The BFD test consisted of five gunnery tasks performed under both day and night conditions and various own and target motion conditions. The vehicle recognition test required participants to identify six different vehicles from about 1800 meters. The tracking test required the gunner to keep the intersection of his sight crosshairs on a moving target.

(2) Phase II: This phase involved administration of a pretraining proficiency test followed by group training. The U-COFT group was given a U-COFT test assessing the beginning skill level of each crew. The baseline group was given a test composed of a subcaliber firing exercise using the M179 Telfare to assess the beginning skill level of each baseline crew. The groups were then trained according to their separate programs of instruction. Upon completion of training, each group was given a posttraining proficiency test that was identical to the pretraining test.

(3) Phase III: This phase consisted of a posttraining examination identical to that of phase I. After this phase, both groups participated in degraded mode gunnery exercises on U-COFT.

d. Number of Different Types of Measures Used: 6

e. Description of Measures/Ratings: The six measures of performance (MOPs) from the U-COFT test were: (1) percentage of first round hits (number of first round hits divided by the total number of possible first round hits); (2) average time first round fired (time target up to first round hit); (3) average

acquisition time (time target up to first crew alert); (4) average time of tracking on target (time of tracking on target divided by possible time); (5) average number of targets correctly identified (number of correctly identified targets divided by the number of personnel); and (6) average time to correctly identify targets (sum of time to correctly identify targets divided by the number of targets correctly identified).

Note: Training effectiveness was defined as the difference between pretraining and posttraining proficiency tests (device proficiency). Training transfer effectiveness was defined as the change in group proficiency from the beginning of Phase I to the conclusion of Phase III (tank proficiency). The difference in proficiency between the groups posttraining proficiency test (Phase I) and the test administered in Phase III was defined as training transfer.

f. Experimental Setting/Training Context: Training was conducted in both institutional and field settings using (1) U-COFT simulators and experienced Instructor/Operators (I/Os), and (2) M1 tanks with M179 Telfare devices. Training examinations were conducted at tank gunnery ranges that incorporated targets located at engagement ranges predicted for a Central European environment in the 1980-1990 time period. Both dry-fire and live-fire exercises were conducted.

g. Statistical Methods: The data were analyzed using oneway analysis of variance, t-test, Chi-squared test, Pearson Product Moment correlation, Wilcoxon ranked-signs test, and the Mann-Whitney test.

h. Stage of Training: Additional gunnery training

i. Trainee Sophistication: Intermediate

j. User Acceptance or Attitude: Several surveys instruments were administered to assess soldiers' general attitudes, ratings of equipment usefulness, and evaluation of the training process.

5. Discussion:

a. Major Findings:

(1) Both training programs were found to be training transfer effective. Five of the six MOPs for the baseline group and four of the six MOPs for the U-COFT trained crews indicated that they were training transfer effective.

(2) No significant difference was found in the amount of transfer effectiveness between the two training programs.

(3) The U-COFT training program was found satisfactory for sustaining gunnery skills, based on percentage of first round hits, average time to fire first round, and average time to acquire the first target.

(4) Final hit performance scores of the baseline group on the BFD test were significantly higher than entry scores and final scores of the U-COFT group.

(5) A significant difference was found between the first round hit performance of the two U-COFT companies. The rationale for this finding was not provided.

(6) Data from the survey questionnaires revealed that almost all respondents were very satisfied with the U-COFTs gunnery instructional capabilities, communications, crew coordination, and feedback factors. Some dissatisfaction, however, was expressed with the target identification training capabilities of the U-COFT.

b. Authors' Conclusions: The author's noted that both the baseline and U-COFT training programs maintained soldier's proficiencies on M1 gunnery tasks. They also demonstrated the cost-effectiveness of U-COFT training compared to only M1 training. Finally, they concluded that soldiers trained in the U-COFT transition training program did not demonstrate as high proficiency on M1 gunnery tasks as those trained on the M1 during the M1 tank Operation Test (OT) III, even though the students felt that the U-COFT was a useful device for transition training. Kuma and McConville (1982), with respect to this study, concluded the confounding and mixed results of the BFD test for the U-COFT group and U-COFT system and station malfunctions indicate a need for additional testing using a larger sample size over an extended time period.

c. Limitations:

(1) Small numbers of available M1 trained crews may have affected the ability to detect and attribute differences in crew proficiency.

(2) Crews were not grouped according to ability (not homogeneous). This may have biased the performance scores.

(3) The baseline training program included training for the entire crew while the U-COFT training program provided training for only the TC's and gunners.

(4) The test may not have been long enough to fully address sustainment training, reliability, or maintainability issues.

(5) Platoon leaders, platoon sergeants, and master gunners of the U-COFT group were trained as I/Os as well as TCs during the test.

(6) Measures of reticle lay error and range error were not collected; thus, no conclusions were made about these issues.

(7) Inconsistent range conditions during the live-fire test led to difficulty in target acquisition and engagement. For example, dust caused by firing and tank movement cleared quickly during the baseline group's test, but took longer to disperse on the following days when the U-COFT group fired.

(8) U-COFT tank crew attitudes may have been negatively influenced because they were required to attend U-COFT training when the rest of the unit was off duty. Because they received no compensatory time, the crews felt they were unfairly treated, and this may have affected their training.

(9) The commander of the baseline company was physically present for virtually all of the baseline training program, while the commanders of the U-COFT companies were not able to visit each crew being trained.

d. Considerations:

(1) There was no round-to-round dispersion on the U-COFT as there is on the M1 tank.

(2) Targets were more distant from the background on the U-COFT terrain scene than on the live-fire range.

(3) The area in which a round impacted and was scored a hit on the U-COFT was defined as the smallest rectangle completely containing the target hull and turret, excluding the gun tube. This created a larger target area than an actual target vehicle presents.

6. Related Work:

a. Hughes, C. R., Butler, W. G., Sterling, B. S. & Berglund, A. W. (1987). M1-Unit Conduct-of-Fire Trainer post fielding training effectiveness (TEA-16-87) White Sands Missile Range, NM: U.S. Army TRADOC Analysis Command. (AD B113 298)

b. Kuma, D., & McConville, L. (1982). Independent evaluation report for M1/M60 series Unit Conduct of Fire Trainer (UCOFT) (TRADOC ACN 39373). Fort Knox, KY: U.S. Army Armor Center, Directorate of Training Developments. (AD B065 441)

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8. Campshure, D. A., & Drucker, E. H. (1990). Predicting first-run gunnery performance on tank table VIII (ARI Research Report 1571). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A228 201)

1. Topic Keywords: Armor; Training Devices; U-COFT; Armor Training; Tank Gunnery; Performance Testing: Tank Table VIII.

2. Short Summary: This research examined whether performance on the first run of Tank Table (TT) VIII can be predicted from the amount and level of training on the Unit-Conduct of Fire Trainer (U-COFT) and from crew turbulence data. During Phase I, intercorrelations were computed between predictor variables and TT VIII measures obtained from 77 M1 tank crews. The results revealed that two predictor variables from U-COFT training correlated significantly with TT VIII performance--crew reticle aim level and tank commander (TC) reticle aim level. Neither variable was able to predict which tank crews would qualify on TT VIII, but the composite of crew reticle aim level and time in crew predicted which crews would qualify. This finding, however, was not supported by the results obtained from 136 M1 tank crews examined during Phase II. Because gunnery training was curtailed during Phase I but not during Phase II, the Phase I results may be applicable to future armor training situations where resource constraints curtail training.

3. Performing Organization: Human Resources Research Organization (HumRRO), 5001 Eisenhower Avenue, Alexandria, VA: 22314.

4. Approach: Analytical

a. Number of Groups: 2

b. Description of Groups: During Phase 1, the data group consisted of two M1 tank battalions (77 crews) from a Continental U.S. (CONUS) post. During Phase 2, the data group consisted of four M1 tank battalions (136 crews) from two CONUS divisions.

c. Tests or Trials:

(a) Predictor Variables: The two sets of variables were related to (1) U-COFT training and (2) tank crew turbulence. The two U-COFT measures were U-COFT proficiency and amount of U-COFT training, both of which were obtained from training printouts from the TC and crew U-COFT matrices. The two indicators of U-COFT proficiency were the reticle aim level achieved by the TC in the TC matrix and reticle aim level achieved by the crew in the crew matrix. The four indicators of amount of U-COFT training were the number of computer recommended exercises completed by the TC in the TC matrix, total number of exercises (computer recommended plus Instructor Operator (I/O) selected exercises) completed by the TC in the TC matrix, number of computer recommended exercises completed by the crew in the crew matrix, and number of exercises completed by the crew in the crew matrix. The single selected measure of crew turbulence was the total number of months that the TC and gunner had served together in the same crew, as TC and gunner.

(b) Performance Variables: The performance variables were the five measures of TT VIII performance and three measures of main gun performance calculated as an alternative to the usual means of measuring gunnery proficiency on TT VIII.

d. Number of Different Types of Measures Used: 8

e. Description of Measures/Ratings: On TT VIII, each crew fired the same six day and four night engagements, selected from among the 14 target engagements described in FM 17-12-1 (Department of the Army, 1988). The information recorded on the TT VIII scoresheets for each first-run engagement was used to calculate the five measures of TT VIII performance: (1) average raw score, (2) average opening time, (3) percent hits, and (4) average crew cuts. Averages were used so that crew data missing for one or more tasks could be included in the analyses. The three main gun performance measures were (1) firing rate, (2) hit proportion, and (3) hit rate. Firing rate (rounds/time) indicated how fast crews fired, regardless of accuracy. Hit proportion (hits/rounds) indicated firing accuracy. Hit rate (hits/time) indicated the speed with which crews achieved hits. Hoffman and Witmer (1989) suggested using the composite metric Hit Rate (hits/time = hits/rounds x rounds/time) as the primary measure of crew gunnery performance. When Hit Rate is weighted by the number of targets presented, the resulting composite metric then includes the variables of hits, time, and targets.

f. Experimental Setting/Training Context: The data were from tank crews trained in an institutional setting using the U-COFT and tested in a live-fire field setting on Table VIII. The crews followed the standard U-COFT program of instruction (POI) for sustainment training of M1 gunnery skills (U.S. Army Armor Center, 1985). In Phase I, variables relating to U-COFT training and crew turbulence were examined to determine their ability to predict TT VIII performance. U-COFT variables were measures of proficiency and amount of training. Crew turbulence focused on the amount of time that the TC and gunner were together in those positions in the same crew. Gunnery performance data were extracted from the TT VIII scoresheets (first-run) provided by the participating battalions. These data were used to calculate five measures of TT VIII performance (average raw score, average opening time, percent hits, average total score, and crew cuts and three main gun performance measures (firing rate, hit proportion, hit rate). In Phase II, the only predictor variables available for analysis were crew reticle aim level and time in crew. Average total score on TT VIII was the only gunnery performance measure available.

g. Statistical Methods: The data were analyzed using the Statistical Package for the Social Sciences (SPSS). Descriptive statistics were calculated to summarize: (1) measures of first-run performance on TT VIII; (2) measures of major portions of TT VIII performance (separate summary statistics for day, night, offensive, and defensive tasks); and (3) three predictor variables (U-COFT proficiency, amount of U-COFT training, and crew turbulence). Intercorrelations were calculated: (1) among predictor variables, (2) among performance measures, and (3) between the predictor variables and the performance measures. Regression analyses were calculated to form multiple regression equations using the predictor composites. Predicted average

total scores were then calculated from these composite equations and plotted against average total scores to determine the utility of the predictor composites.

h. Trainee Sophistication: M1 TCs and gunners with a wide range of gunnery experience levels.

5. Discussion:

a. Major Findings:

(1) In Phase I, only 24 of 77 crews (31%) qualified on TT VIII during their first-run performance. Their mean TT VIII score was 612.9. In Phase II, the mean TT VIII score was 742.0; some 130 points greater than that obtained by crews in Phase I.

(2) Many tank crews did not practice on U-COFT under all of the engagement conditions required on TT VIII. In Phase I, tank crews attained a mean reticle aim level of 26.29 compared to 20.80 in Phase II. In Phase I, the average crew reached reticle aim group four in the crew matrix compared to reticle aim group three in Phase II.

(3) Tank crew turbulence was high, confirming that this is a major problem for unit trainers. In Phase I, only 50% of the crews were together for more than three months, 25% together more than six months, and 4% together more than a year. In Phase II, 50% were together for more than two months, 31% more than three months, 22% more than six months, and 9% more than a year.

(4) The correlation between reticle aim level and time in crew (.38) in Phase I was significant and comparable to the correlation between those same variables obtained in Phase II (.39).

(5) In Phase I, crews that had been together longer and had more time to train on U-COFT performed better on U-COFT. All six U-COFT related variables correlated significantly with each other. Also, all six variables except TC computer exercises and TC total exercises correlated significantly with time in crew.

(6) In Phase I, crew reticle aim level correlated significantly with average total score and hit rate on TT VIII, as did TC reticle aim level with the average total score on TT VIII. Time in crew was not significantly correlated with any of the performance measures. In Phase II, crew reticle aim level was not significantly correlated with average total score on TT VIII or any of its major components. However, time in crew was significantly correlated with average total score on TT VIII (.22), day tasks (.21), and offensive tasks (.29).

(7) In Phase I, regression analysis indicated that the individual correlations between crew and TC reticle aim levels and total score were not sufficiently robust to allow prediction of TT VIII performance from reticle aim level alone. As found,

these were the only two predictor variables that correlated significantly with average total score on TT VIII.

(8) In Phase I, multiple correlations using the two variable composites resulted in higher correlations than were obtained using single predictors. For example, the multiple correlation between average total score and the composite of crew reticle aim level and time in crew was .46 and accounted for 21% of the TT VIII total score variance.

(9) In Phase I, if crews had been required to attain an expected score of 700 before being allowed to fire TT VIII, only 12 crews would have fired without getting additional training. Half would have qualified, and half would have failed. However, if all crews were allowed to fire regardless of expected outcome, only 31% would have qualified and 69% would have failed TT VIII. Using the predictor variables to determine which crews would be allowed to fire TT VIII would have increased the percentage of crews that qualified from 31% to 50% and decreased the percentage of crews that failed to qualified from 69% to 50%.

(10) In Phase II, the correlation between predicted and actual score was not significant (-.06) and did not approach the correlation obtained during Phase I (.46). Also, the same two predictor variables accounted for only 5% of the TT VIII total score variance, all of which was accounted for by time in crew.

b. Authors' Conclusions:

(1) Both crew and TC reticle aim level correlated significantly with TT VIII performance in Phase I, but neither was able to predict which crews would qualify on TT VIII.

(2) A composite of crew reticle aim level and time in crew predicted which crews would qualify, but this finding was not supported by Phase II results.

(3) Because gunnery training was curtailed during Phase I but not Phase II, the Phase I results may be applicable to future training where resource constraints may be curtailed.

c. Limitations:

(1) The TT VIII data may not be representative of the population of armor units. Hoffman (1989) reported that 95.5% of crews passed TT VIII at Grafenwoehr. This is considerably higher than the 31% of crews that passed TT VIII during Phase I.

(2) The results suggest that the prediction model (regression equation based on composite of crew reticle aim level and time in crew) derived during Phase I is applicable only to the sample on which it was based. During Phase II, only 29% of the predictions were accurate. Of the inaccurate predictions, 70% were false negatives (crews predicted to fail that passed), and 1% were false positives (crews predicted to pass that failed).

d. Considerations: The discrepancy between the two sets of results may have been due to differences in gunnery training. The tank battalions that participated in Phase I were restricted by mileage to only one Tank Crew Proficiency Course, but battalions participating in Phase II had no such restrictions. This may have inadvertently caused Phase I to be a more accurate image of future training conditions than Phase II. If so, more credence should be given to the Phase I rather than Phase II results.

6. Related Work:

a. Department of the Army (1988). Tank combat tables M1 (Field Manual 17-12-1, C3). Washington, DC: Author.

b. General Electric (1985). Instructor's utilization handbook for the M1 Unit-Conduct of Fire Trainer (U-COFT) (Vol.1). Orlando, FL: Naval Training Equipment Center.

c. Hoffman, R. G. (1989). Description and prediction of Grafenwoehr M1 tank table VIII performance (ARI Technical Report 837). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD B136 331)

d. Hoffman, R. G., & Witmer, B. G. (1989). Development of a Unit-Conduct of Fire Trainer (U-COFT) test of M1 gunnery proficiency (ARI Technical Report 859). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A219 045)

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9. Campshure, D. A., Witmer, B. G., & Drucker E. H. (1990). The effects of amount of M1 Unit Conduct-of-Fire Trainer (U-COFT) transition training on crew gunnery proficiency (ARI Research Note 90-03). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A219 924)

1. Topic Keywords: Armor; M1 Tank; Tank Gunnery; Simulators; U-COFT; Skill Acquisition; Performance Measurement.

2. Short Summary: This research examined the effects of three types of variables on crew M1 Unit Conduct-of-Fire (U-COFT) tank gunnery proficiency during transition training: the 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., class hours, time spent on the M60A3 U-COFT). The reliability of the gunnery proficiency test was also assessed. Three groups of tank commander (TC)-gunner teams were tested after they completed three, six, or nine hours of M1 U-COFT transition training. Time on 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 suggested that learning may have taken place despite the failure

to detect improvement on the six other measures. Although the three groups differed significantly on a number of training-based variables, only number of exercises completed in the TC training matrix had an effect on any of the measures. The reliability of all measures exceeded .50, with two measures exceeding .70.

3. Performing Organization: Human Resources Research Organization (HumRRO), 1100 S. Washington Street, Alexandria VA 22314.

4. Approach: Experimental

a. Number of Groups: 3

b. Description of Groups: The subjects were 68 M60A3 tank crews from two different battalions who were in the process of transitioning to the M1 tank. The crews were randomly assigned to one of three groups based on three, six, or nine hours of M1 U-COFT training. After being tested, the crews continued with their normal U-COFT transition training.

c. Tests or Trials: The M1 U-COFT gunnery proficiency test (UGPT) developed by Hoffman and Witmer (1989) was used to assess U-COFT proficiency. The one hour test was administered by one of two trained, non-military Instructor/Operators (I/Os). This allotted hour immediately followed the crew's third, sixth, or ninth hour of transition training on the M1 U-COFT. The test administrators completed a Biographical Questionnaire for each soldier who participated in the research.

d. Number of Different Types of Measures Used: 3.

e. Description of Measures/Ratings:

(1) U-COFT Gunnery Proficiency Test (UGPT): 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 crews'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.

(2) Soldier-based Predictor Variables: The following variables from the biographical questionnaire were included in the analyses as measures of experience: time in armor, time in position, and time with partner. Scores on the Armed Service Vocational Aptitude Battery (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 measure 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 roughly equivalent to intelligence test scores. GT score is one criteria used to select soldiers for Officers Candidate School.

(3) Training-Based Predictor Variables: Information as to the number of hours spent during transition training in the classroom and on the M1 tank was extracted from the biographical questionnaire. Also extracted was the amount of time each TC and gunner had spent on the M60A3 and M1 U-COFT systems prior to the administration of the UGPT. U-COFT printouts were used to collect information reflecting performance of each crew at the time the crew was tested and after nine hours of transition training on the M1 U-COFT. 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.

f. Experimental Setting/Training Context: The tank crews were in the process of transitioning from the M60A3 to the M1 tank. All tank gunnery transition training was conducted by the New Equipment Training Team, except for the UGPT administration. To assure standardized test administration procedures, the two non-military I/Os received instruction from the researchers which detailed how to administer the UGPT without providing performance feedback, the importance of not altering the directions read to each tank crew, and the difference between testing and training. The I/Os were also required to run through several practice UGPT administrations prior to the start of testing.

g. Statistical Methods: The data analyses were conducted in four phases. First, analysis of variance (ANOVA) was computed to compare the three groups in terms of the soldier-based predictor measures, training-based predictor measures, and the criterion measures. Second, correlations were computed between predictor variables and the criterion measures. Third, intercorrelations were computed within each of the two sets of predictor variables and within the set of criterion measures. Forth, the reliability of the UGPT was assessed by computing Spearman-Brown correlation coefficients to determine the test's internal consistency.

h. Stage of Training: Transition training.

i. Use of Instructional Features: A set of standardized administration procedures were followed, which included verbatim reading of instructions at the start of each exercise. The I/Os were not allowed to provide feedback or coaching during testing, and switch setting instructions were provided only at the start of each exercise.

5. Discussion:

a. Major Findings:

(1) The three groups failed to differ on any soldier-based predictor variable, but did differ on all training predictor variables except number of hours spent on the M60A3 U-COFT and number of hours of transition classroom training.

(2) The time spent on the M1 U-COFT resulted in improved gunnery performance on only one of seven criterion measures--average miss distance. Because 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.

(3) In general, the correlations between soldier-based and training-based predictor variables and criterion measures were contrary to expectations and difficult to interpret.

(4) All intercorrelations among the criterion measures were significant except for system management errors. All training-based U-COFT measures were highly correlated as well.

(5) A significant relationship was found between total number of exercises completed in the TC and TC/gunner matrices and five criterion measures (overall hit and fire rate, average opening time and miss distance, and target acquisition errors).

(6) Significant relationships were 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.

(7) The reliability coefficients ranged from .51 to .77 for the various criterion measures, and are generally consistent with the test-retest reliabilities previously reported by Graham (1986), Du Bois (1987), and Witmer (1988).

b. Authors' Conclusions:

(1) Increasing number of hours of transition training on the M1 U-COFT resulted in improved gunnery performance on only one criterion measure; average miss distance.

(2) Given that the average miss distance is the most sensitive measure of gunnery proficiency, the results suggest that skill acquisition occurred but further training was needed.

(3) The failure to find any improvements on five of the seven criterion measures may have been the result of lack of test sensitivity rather than lack of learning.

(4) Prior U-COFT experience and predominance of moving tank engagements on the criterion test were eliminated as likely causes for the failure to obtain significant correlations.

(5) The UGPT was found to be sufficiently reliable to be used as a means of evaluating crew gunnery proficiency.

c. Limitations:

(1) The UGPT was not administered after M1 U-COFT sustainment training, wherein crews progress through the remainder of the TC and TC/gunner matrices, to better determine the reliability of the criterion measures and the overall test.

(2) A pretest of gunnery proficiency would have determined whether completing an increased number of U-COFT exercises or attaining a higher reticle aim level in the U-COFT matrices was the result of more proficient TCs and gunners.

d. Considerations: A major problem in device testing has been the frequent use of samples that are too small in relation to the variability of performance, so that the statistical power to detect differences of a reasonable size has been inadequate. A second problem in device testing is that the amount of training (e.g., three, six, and nine hours of U-COFT training) may be insufficient to affect proficiency.

6. Related Work:

a. Department of the Army (1985). Tank combat tables M1 (Field Manual 17-12-1). Washington, DC: Author.

b. 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, Bowling Green, KY.

c. Graham, S. E. (1986). The Unit-Conduct of Fire Trainer (U-COFT) as a medium for assessing gunnery 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)

d. Hoffman, R. G., & Witmer, B. G. (1989). Development of a Unit-Conduct of Fire Trainer (U-COFT) test of M1 gunnery proficiency (ARI Technical Report 859). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A219 045)

e. Smith, M.D., & Hagman, J. D. (1992). Predicting Table VIII tank gunnery performance from M-COFT hit rate and demographic variables (ARI Technical Report 955). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A254 580)

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

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10. 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)

1. Topic Keywords: Armor; M1 Tank; Tank Gunnery; Simulators; Training Devices; U-COFT; Test and Evaluation; Performance Test; Test Construction.

2. Short Summary: A device-mediated M1 tank gunnery test was developed for administration on the Unit-Conduct of Fire Trainer (U-COFT). This research examined the test's reliability and utility for estimating tank gunner's proficiency, independently of the tank commander's (TC) contribution. The results revealed that the reliability for six of the nine U-COFT measures was greater than .70 and for three of those measures, at least .80. The gunners' hit rates were found to be heavily influenced by the TC's performance, including the TC's ability to train. As such, TC performance must be stabilized if the U-COFT tests are to be used to assess gunners' performance alone. Recommendations were made as to how the U-COFT could be used efficiently in units as a training and testing device.

3. Performing Organization: U.S. Army Research Institute for the Behavioral and Social Sciences, ARI Field Unit - Fort Knox, Fort Knox, KY 40121-5620.

4. Approach: Experimental

a. Number of Groups: 1

b. Description of Group: The group consisted of 32 M60A3 tank loaders and drivers. These armor crewmen had just completed participating in U-COFT research (Witmer, 1988), where they were randomly paired with one of four TCs and received one and one-half hours of U-COFT training. Most tank crewmen had the rank of Private First Class and had not served as gunners other than in Advanced Individual Training (AIT). None had M1 tank experience.

c. Tests or Trials: The U-COFT gunner's test consisted of eight shortened exercises from the U-COFT's TC/gunner's training matrix; each contain d four engagements. The exercises were presented sequentially with a short pause between each to allow resetting the device for the next exercise. Because one of the targets was friendly (M2), the total test consisted of 31 target engagements. The exercises were selected using a matrix sampling approach to match conditions found in Tank Table (TT) VIII of the M1 tank combat tables (FM 17-12-1, Department of the Army, 1985). As such, the U-COFT gunner's test differed from TT VIII in that it: (1) contained only main gun engagements fired by the gunner, (2) contained no Nuclear, Biological, Chemical (NBC) conditions, (3) included a greater proportion of degraded mode conditions, and (4) included simulated battlefield distractions; e.g., friendly and enemy fire. The U-COFT gunner's test was given

twice (test, retest), with exercises presented in a different order for the retest. Each test administration took about 45 minutes, with a 10-15 minute break between tests (total test time was about two hours). Twelve sessions (42 hrs) were required to test all 32 gunners.

d. Number of Different Types of Measures Used: 9

e. Description of Measures/Ratings: The nine measures of gunnery performance were: (1) hit rate (number of hits divided by number of targets presented); (2) first round hit rate; (3) azimuth aiming errors; (4) elevation aiming errors; (5) target identification (ID) time (time from when the target appeared until the gunner announced "Identified"; (6) opening time (the time from target appearance until the first round was fired); (7) Target Acquisition score; (8) Reticle Aim score; and (9) System Management score. The last three measures are provided by the U-COFT software package (General Electric, 1985).

f. Experimental Setting/Training Context: The research was conducted in an institutional setting using standardized sets of instruction for both hands-on training and testing. The gunners were randomly paired with TCs who were either: (1) COFT-experienced, (2) a senior Noncommissioned Officer (NCO), or (3) a junior NCO. The U-COFT gunner's test began with eight practice target engagements. The last four engagements required use of the GAS as there was simulated failure of the laser rangefinder (LRF), stabilization system, GPS, and computer system. The TC trained the gunner on use of the GAS and how to fire with manual lead and elevation. The eight U-COFT test exercises with four engagements were sequentially presented with a short pause between each. During this time, the U-COFT I/O terminated the standard 10 engagement exercise, dumped the printouts, and then entered the six-digit code for the next subtest. Following a 10 minute break, a retest was presented which consisted of a different exercise order. The test and retest each took about 45 minutes, with the entire procedure lasting about two hours. To minimize the effects of differential TC performance, gunnery procedures were modified by having the Instructor/operator (I/O) talk the gunner onto the target, and omitting the U-COFT procedures which require the gunner on defensive engagements to move his head out of the Gunner's Primary Sight (GPS), check the Gunner's Auxiliary Sight (GAS) to ensure the main gun has cleared the berm, announce "driver stop", and return to the GPS.

g. Statistical Methods: Data were analyzed using the Statistical Package for the Social Sciences (SPSS). Mean test and retest scores, and Pearson r reliability coefficients were calculated for the nine U-COFT performance measures. An analysis of variance (ANOVA) statistical technique was used to determine the effects of U-COFT performance as a function of TC experience. Stepwise regression analyses were performed to assess factors underlying the various performance measures.

h. Trainee Sophistication: Novice M1 gunners

i. Use of Instructional Features: Fully, except for the modifications made to minimize the effects of differential TC performance.

5. Discussion:

a. Major Findings:

(1) The reliability for six of the nine U-COFT measures was greater than .70, and for three measures, at least .80. Poor reliability was found for azimuth errors (.42), elevation errors (-.07), and the U-COFT System Management scores (.11).

(2) U-COFT performance was found to differ as function of TCs' performance. Gunners paired with the COFT-experienced TC had a combined test and retest hit rate of 74%, while TCs paired with the Senior NCO shot 64%, and those with the Junior NCO shot 63%. These differences were found statistically significant, as were those for first round hit rate, ID time, and the Reticle Aim, Target Acquisition, and System Management scores.

b. Authors' Conclusions:

(1) The U-COFT test was found reliable, and therefore a potentially valid means for assessing tank gunnery proficiency. Moreover, it can be used in the development of combat attrition models and as criteria against which other less expensive part-task tests can be validated.

(2) Device-mediated tests such as with the U-COFT offer certain advantages over hands-on performance tests including standardized test administration and scoring, and the inexpensive capability of building longer, more varied tests. The U-COFT tests can also be used to partial out the relative contribution of individual crew members in whole-task gunnery engagements.

(3) The U-COFT proficiency test developed for this research mirrored target conditions in the M1 TT VIII, but this may not be necessary. Psychomotor skills and system procedural knowledge are highly redundant across engagement conditions. As a result, it is unlikely that a crew who is relatively good at long range moving targets at night would be poor at short range stationary targets in daylight.

(4) Skills and abilities other than those measured by the U-COFT are equally important and should not be overlooked. In this research, the results showed that the TC's ability to train his gunner heavily influenced gunnery performance.

c. Limitations: DuBois (1987) sought to replicate the research by testing more soldiers (165), all of whom were M1 entry-level tankers with no U-COFT experience. DuBois's data indicated significant test/retest correlations, but they were lower in magnitude. Only two of the nine measures used by Graham exceeded .70 and most were in the .20 to .50 range.

d. Considerations: This research provides a reliable and valid U-COFT test that can be used to assess gunner proficiency; thus, reducing the relative contributions of the tank commander during target engagements. Doubts about the reliability of most of the nine U-COFT measures have surfaced to warrant studying the acquisition characteristics of U-COFT in detail. Measures of the stability of performance such as within-crew variances and trial-to-trial correlations need to be determined. Such data can then be used to estimate the number of repeated exercises required to obtain stable estimates of performance. In addition, a U-COFT Test of Gunner Proficiency (CTGP) has been developed by Hoffman and Witmer (1989) which produces a composite measure of gunnery proficiency called "hit rate" which captures in a single metric the essential elements of gunnery success: rounds fired, time expended, accuracy of fire, and completeness (all targets hit?).

6. Related Work:

a. Department of the Army (1985). Tank combat tables M1 (Field Manual 17-12-1). Washington, DC: Author.

b. DuBois, 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, Bowling Green, KY.

c. General Electric (1985). Instructor's utilization handbook for the M1 Unit-Conduct of Fire Trainer (U-COFT) (Vol.1). Orlando, FL: Naval Training Equipment Center.

d. Hoffman, R. G., & Witmer, B. G. (1989). Development of a Unit-Conduct of Fire Trainer (U-COFT) Test of M1 gunnery proficiency (ARI Technical Report 859). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A219 045).

e. Smith, M.D., & Hagman, J. D. (1992). Predicting Table VIII tank gunnery performance from M-COFT hit rate and demographic variables (ARI Technical Report 955). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A254 580)

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11. Graham, S. E., & Smith, T. L. (1991). Identifying tank gunnery skill requirements on the Institutional-Conduct of Fire Trainer (I-COFT) (ARI Research Report 1583). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A235 597)

1. Topic Keywords: M1 Tank; Gunnery Training; Training Devices; I-COFT; U-COFT; Training Strategy; Performance Measurement; EIA.

2. Short Summary: This research was intended to facilitate the refinement of future Armor device-based training strategies by developing a set of analytical methods that could be used to quantify changes in (a) gunnery speed and accuracy, (b) relative rates of skill development, and (c) tank gunnery patterns. An Institutional-Conduct of Fire Trainer (I-COFT) gunnery test was administered twice to 18 soldiers enrolled in the initial-entry Excellence in Armor (EIA) program, both before and after 14 hours of EIA I-COFT training. The I-COFT test was also administered to 10 Noncommissioned Officer (NCO) gunnery instructors from the U.S. Army Armor School. Comparison of changes in performance resulting from the 14 hours training and differences in gunnery performance between EIA soldiers and NCOs were made, as well as a comparison of I-COFT and Unit-Conduct of Fire Trainer (U-COFT) devices. The results of the research revealed that (a) EIA soldiers were considerably more accurate and faster after being trained on I-COFT; (b) NCOs were consistently faster than EIA soldiers on both stationary and moving targets, but not more accurate on stationary targets; (c) stationary target misses by EIA soldiers were due mostly to aiming too high or low; (d) moving target misses by EIA soldiers were due to poor tracking; (e) a global measure of controlled tracking skills was able to account for the speed and accuracy differences on both stationary and moving targets.

3. Performing organization: U.S. Army Research Institute for the Behavioral and Social Sciences, ARI Field Unit - Fort Knox, Fort Knox, KY 40121-5620.

4. Approach: Experimental

a. Number of Groups: 2

b. Description of Groups:

(1) Excellence in Armor (EIA) Group: This group was composed of 18 soldiers from three 1st Armored Training Brigade companies enrolled in One Station Unit Training (OSUT). The EIA program accepts a maximum of 10% of highly selected volunteers from each company to receive extra training (14 hours with I-COFT and additional peer leadership responsibilities).

(2) Non-Commissioned Officers (NCOs) Group: This group was composed of 10 NCOs serving as gunnery instructors in the U.S. Army Armor School Weapons Department. Each NCO had extensive experience with the I-COFT.

c. Tests or Trials: The I-COFT gunner's test contained four exercises (I-COFT Exercise Numbers 31311 (as warm-up), 32211, 33211, & 32311) from the I-COFT's Target Engagement Practice Exercises (TEPE). These exercises included 10 targets that were at short and long ranges, moving and stationary. Only exercise 33?'1 involved engaging multiple (2) targets. The soldiers own vehicle was always stationary. The test used I-COFT's synthetic Tank Commander (TC) instructional feature. The EIA soldiers were

tested after normal OSUT I-COFT training (pretest) and again after additional EIA I-COFT training (posttest). The NCOs were tested once on the I-COFT and once on the U-COFT.

d. Number of Different Types of Measures Used: 3

e. Description of Measures/Ratings:

(1) Timing measures: Each target engagement was scored in terms of (a) Acquisition Time, the time from when the target appeared until the gunner reached the target with reticle; (b) Lase Time, the time from when the reticle reached the target until the gunner lased with the laser range finder; (c) Fire Time, the time from when the gunner lased until he fired; and (d) Opening Time, the time from when the target appeared until the gunner fired and calculated by summing the first three times.

(2) Error measures: Target engagements were reviewed to determine why rounds missed targets. That is, (a) aiming errors were reviewed to determine if the aim was too high, low, in front of, or in back of the target; (b) tracking errors were reviewed to include tracking too fast, too slow, erratically, or with the wrong lead; and (c) procedural errors were reviewed to include firing the wrong weapon, indexing the wrong ammunition, or failing to lase.

(3) Performance measures: Performance measures were obtained from the I-COFT printouts. This included (a) hit probability, (b) first round hit probability, (c) hit rate (number of targets that would be hit per minute), (d) opening time, and (e) azimuth and elevation errors.

f. Experimental Setting/Training Context: Training and testing was conducted in an institutional training facility using the I-COFT and U-COFT simulators and Instructor/Operators (I/Os).

g. Statistical Methods: T-tests, correlations, and regression analyses were used to examine the performance of EIA and NCO groups.

h. Stage of Training: EIA training

i. Trainee Sophistication: EIAs (novices); NCOs (masters)

5. Discussion:

a. Major Findings:

(1) After 14-hours of EIA I-COFT training, the soldiers were considerably more accurate and faster than before training.

(2) NCOs were consistently faster than EIA soldiers on stationary and moving targets on I-COFT. Thus, skills needed to accurately engage moving or multiple targets develop slowly.

(3) No differences in I-COFT accuracy on the stationary targets were found between EIA and NCO soldiers. This was not unexpected; few gunners miss stationary targets. Thus, skills needed to accurately engage stationary targets develop quickly.

(4) The tracking ratings were excellent predictors of I-COFT hit rate on moving and stationary targets. This means that by observing how well a gunner tracks a set of moving targets, it is possible to predict how he would do on moving and stationary targets for both speed and accuracy.

(5) Stationary target misses on I-COFT were the result of aiming too high or low. Moving target misses were the result of poor tracking.

(6) Tracking ability on the I-COFT mostly accounted for speed and accuracy performance for stationary and moving targets.

(7) There were few differences in performance using the I-COFT with a synthetic TC and U-COFT with a live TC. The main difference was in target acquisition time. Because the computer knows the target's location, it can direct the gunner faster than the live TC who has to scan to locate the target. As a result, target acquisition times were faster using I-COFT than U-COFT.

b. Authors' Conclusions:

(1) The 14 hours of I-COFT training between the pre- and posttests resulted in improved gunnery accuracy and speed for EIA soldiers.

(2) By identifying certain patterns of gunnery errors, training emphasis can be tailored to improve performance.

c. Limitations:

(1) Because the research did not include a control group which did not receive the 14 hours of additional I-COFT training, the changes in EIA performance cannot be credited unequivocally to the I-COFT training received between the pre- and posttests.

(2) While this research did find significant differences between the EIA and NCO training groups, the number of soldiers in each group was small. Boldovici & Sabat (1986) caution that small sample size in comparison groups limit the generalizability of a research finding from those groups to an entire MOS.

d. Considerations: The author's intent was to develop a set of analytical methods that could be used to quantify changes in gunnery speed and accuracy, relative rates of skill development, and tank gunnery patterns. In the development of Armor device-based training strategies, the demonstration of positive skill acquisition and improvement using the I-COFT should be noted.

6. Related Work:

a. Boldovici, J. A., & Sabat, S. R. (1986). Measuring transfer from training devices to weapon systems (ARI Conference Paper). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

b. Campshure, D. A., Witmer, B. G., & Drucker, E. H. (1990). The effects of amount of M1 Unit Conduct-of-Fire Trainer (U-COFT) transition training on crew gunnery proficiency (ARI Research Note 90-03). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A219 924)

c. General Electric Company (1985). Instructor's utilization handbook for the M1 Unit-Conduct of Fire Trainer (U-COFT) Volume 1: General Information. Daytona Beach, FL: Author.

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

e. Hughes, C. R., Butler, W. G., Sterling, B. S. & Berglund, A. W. (1987). M1-Unit Conduct-of-Fire Trainer post fielding training effectiveness (TEA-16-87) White Sands Missile Range, NM: U.S. Army TRADOC Analysis Command. (B113 298)

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12. Guckenberger, D., Uliano, K. C., & Lane, N. E. (1992). The application of above real-time training (ARTT) for simulators: Acquiring high performance skills [Summary]. Proceedings of the 14th Interservice/Industry Training Systems and Education Conference, 928-935.

1. Topic Keywords: Armor; M1 Tank; Gunnery Training; Training Devices; VIGS; Training Strategy; ARTT; Skill Acquisition.

2. Short Summary: This research compared Above-Real Time Training (ARTT) to conventional training and examined the implementation of different ARTT sequences. ARTT refers to training conducted in a simulated environment that functions at a faster rate than normal or conventional time. Twenty-five male undergraduate students performed three tank gunnery tasks, using the Videodisk Interactive Gunnery Simulator (VIGS), under different levels of time acceleration (1.0x, 1.6x, 2.0x, random, sequential). The results revealed that (a) all accelerated training (1.6x, 2.0x, random, and sequential) produced better performance in real-time than standard real-time training, and (b) random presentation (e.g., 1.0, 2.0, 1.6) was the most effective training strategy of those used.

3. Performance Organization: ECC International Corporation; and University of Central Florida (UCF), Institute for Simulation and Training (IST), P.O. Box 25000, Orlando, FL 32816.

4. Approach: Experimental

a. Number of Groups: 5

b. Description of Groups: The subjects were 25 male undergraduate students from UCF who were randomly assigned to one of five time-acceleration training groups listed below, and were trained and tested on three tank gunnery tasks on VIGS.

(1) Group 1: real time (1.0)

(2) Group 2: 1.6 time acceleration

(3) Group 3: 2.0 time acceleration

(4) Group 4: random presentation of the first three time constants (e.g., 1.6, 1.0, 2.0);

(5) Group 5: sequential presentation of the first three time constants (i.e., 1.0, 1.6, 2.0).

c. Tests or Trials: Each subject received 20 training trials (five of which were familiarization) and six transfer trials. During training, each of the three gunnery tasks was randomly presented five times. During the transfer phase, each gunnery tasks was randomly presented twice in real time.

d. Number of Different Types of Measures Used: 4

e. Descriptions of Measures/Ratings: Th four measures of performance were: (1) opening time (i.e. the time from target presentation to firing the first round), (2) time to kill (i.e., the time from target presentation to the time round strikes the target), (3) azimuth and elevation errors, and (4) hit/miss percentage. A gunnery index was calculated using the opening time, time to kill, azimuth and elevation errors, and hit/miss percentages (Hoffman & Morrison, 1987).

f. Experimental Setting/Training Context: This research was conducted in an institutional setting using a hands-on training and testing approach. Twenty-five undergraduate male students from UCF were randomly assigned to one of five time-acceleration groups (1.0, 1.6, 2.0, random, or sequential). Each subject was then familiarized with the VIGS, during which time they received five practice target engagement trials. During the training phase, each subject performed 15 randomly presented trials of the three gunnery tasks. That is, each gunnery task was performed five times under an assigned time acceleration. After the training phase, subjects were presented with six random transfer trials in real time with each gunnery task presented twice.

g. Statistical Methods: Data were analyzed with the GB-STAT statistical computer package, version 3.0 (Friedman, 1991). Separate analyses of variance (ANOVAs) were conducted for four performance measures (opening time, time to kill, azimuth and elevation errors, hit/miss percentage). Paired comparisons among means were done using least significant difference (LSD) method.

h. Trainee Sophistication: Novice

6. Discussion:

a. Major Findings:

(1) The group trained under random time accelerations (Group 4) had significantly better gunnery indexes and hit/miss percentages in transfer than either of the other four groups.

(2) The group trained under standard time (Group 1) performed significantly worse (on gunnery index and hit/miss percentage) in transfer than in training.

(3) A significant reduction in training time was achieved using ARTT with performance staying equal to or surpassing real-time performance.

b. Author's Conclusions:

(1) ARTT improved novice males' part-task simulated tank gunnery performance.

(2) Accelerated training and ARRT combinations produced better training and transfer than standard real-time condition.

(3) The random ordering of time acceleration trials improved training most.

c. Limitations:

(1) It was not clear how statistically significant results were attained with five subjects in each group, if the groups were equal after assignment, or how the statistical power (.86) was determined.

(2) Results were not reported separately for the time to fire or azimuth and elevation error variables.

(3) No explanation was provided as to why the group that trained using standard time (Group 1) performed worse when tested under standard time during transfer. The implication is that ARTT improves performance, but the authors do not address why conventional training inhibited performance.

(4) Little theoretical justification was provided to explain why random presentation of time acceleration sessions was more effective than other strategies (1.6x, 2.0x, or sequenti l)

d. Considerations:

(1) The VIGS is used to train mostly psychomotor skills, and fewer higher-order cognitive skills. These findings may not be generalizable to other simulated environments that train tactical or team skills.

(2) Because this study used male undergraduates and the VIGS, it is not clear whether these results are generalizable to armor crewmen, other part-task tank gunnery simulators, or actual live-fire tank gunnery.

6. Related Work:

a. Bliss, J. P., Lampton, D. R., & Boldovici, J. A. (1992). The effects of easy-to-difficult, difficult-only, and mixed-difficulty practice on performance of simulated gunnery tasks (ARI Technical Report 948). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A251 866)

b. Cohen, J. (1988). Statistical power analysis for behavioral sciences, (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum.

c. Friedman, P. (1991). GB-STAT[Computer Program]. Silver Springs, MD: Dynamic Microsystems, Inc.

d. Hoffman, R. G., & Morrison, J. E. (1987). Requirements for a device-based training and testing program for M1 gunnery. Volume 1: Rationale and summary of results (ARI Technical Report 783). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A194 808)

e. Schneider, W. (1985). Training high performance skills: Fallacies and guidelines. Human Factors, 25, 285-300.

f. Vidulich, M., Yeh, Y. Y., & Schneider, W. (1983). Time compressed components for air intercept control skills. Proceedings of the 27th meeting of the Human Factors Society, 161-164.

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13. Hart, R. J., Hagman, J. D., & Bowne, D. S. (1990). Tank gunnery: transfer of training From TopGun to the Conduct-of-Fire Trainer (ARI Research Report 1560). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A233 165)

1. Topic Keywords: Armor; M60A3 Tank; Tank Gunnery; Training Devices; TopGun; U-COFT; Training Transfer; Reserve Component.

2. Short Summary: This research examined the effects of TopGun training on M60A3 gunnery performance as measured on the Unit-Conduct of Fire Trainer (U-COFT). Three groups of 16 Reserve Component (RC) soldiers were compared using a training transfer design. Firing under auxiliary sighting conditions, the groups differed on the number of TopGun training sessions (0, 1, or 3) they received before completing a U-COFT test. The results revealed that (a) speed and accuracy on stationary and moving targets improved during TopGun training, (b) TopGun training resulted in increased accuracy on stationary target engagements on U-COFT, and (c) TopGun performance was a reliable predictor of U-COFT performance, with greater correlations for speed than for accuracy. The report also outlined a TopGun-based strategy for increasing transfer to stationary and moving targets, and for enhancing the payoff obtained from TopGun training within the RC.

3. Performing Organization: U.S. Army Research Institute for the Behavioral and Social Sciences, ARI Boise Element, 1910 University Drive, Boise, ID 83725-1140.

4. Approach: Experimental

a. Number of Groups: 3

b. Description of Groups:

(1) Subjects in E1 Training Group: Eight soldiers held the 19E (Armor Crewman) Military Occupational Specialty (MOS) with a duty position of either driver or loader. The other half were non-19E MOSs soldiers who had no tank gunnery experience.

(2) Subjects in E3 Training Group: Same as E1 group.

(3) Subjects in Control Group: Same as E1, E3 groups.

c. Tests or Trials:

(1) Subjects in E1 Training Group: The soldiers got one U-COFT test preceded by one TopGun training session.

(2) Subjects in E3 Training Group: Same as E1 group, except the soldiers received three sessions of TopGun training.

(3) Subjects in Control Group: Same as E1 group, except the soldiers received no training sessions on TopGun.

d. Number of Different Types of Measures Used: 6

e. Description of Measures/Ratings: Soldier performance on TopGun and U-COFT was measured for both accuracy and speed. The measure of firing accuracy was defined as the number of first round hits (rounds within the 100% target kill zone) recorded in each block of 10 targets. Secondary measures were aiming error (distance from point of aim to target center of mass--applied to stationary targets only), and firing efficiency (number of total

hits recorded within a target block divided by the number of rounds fired). The measure of engagement speed was defined as the time from initial target appearance to the time of a first round hit and was averaged across all hits within a block. Secondary speed measures were average hit time, regardless of the round on which the hit occurred, and first-round opening time regardless of outcome. U-COFT "dispersion misses" were examined to determine whether they varied randomly or as a function of treatment conditions. U-COFT "system errors" resulting from targets calling for high-explosive antitank-tracer (HEAT-T) or coaxial machinegun engagements were ignored.

f. Experimental Setting/Training Context: The research was conducted in an institutional setting using a hands-on training approach. TopGun training and U-COFT testing consisted of 40 single-target engagements containing an equal proportion of stationary and moving targets at short and long distances. The TopGun targets were programmed to be similar to U-COFT targets, presented in four counterbalanced blocking orders of 10 targets each, with target presentation sequence randomized within blocks. Experimental groups were given 15 minutes of familiarization and 10 practice trials on TopGun. During training, soldiers could fire as many rounds as possible until the target was either hit or disappeared. Each session took about 20 minutes, with E3 group soldiers receiving 5-minute breaks between sessions. U-COFT testing included 20 minutes of device familiarization and four practice trials. Each U-COFT test session took about 50 minutes and was done by two military U-COFT instructor/operators (I/Os) who role-played the part of the TC. The I/Os laid the gun near the target, issued auxiliary sight fire commands, and then recorded gunner performance. The time interval between TopGun training and U-COFT testing was held to 15 minutes to minimize forgetting (Wells & Hagman, 1989).

g. Statistical Methods: Separate data analysis procedures were used to answer five basic questions, with the rejection region for all analyses being $p<.05$. To determine if gunnery performance improved during TopGun training, a repeated measures analysis of variance (ANOVA) was performed on speed and accuracy scores of E3 group soldiers. A multivariate analysis of variance (MANOVA) preceded univariate analyses to control for Type-I errors. To determine if TopGun training transferred to U-COFT, split-plot ANOVAs, with repeated measures on target distance and movement, were performed on U-COFT speed and accuracy scores. The two degrees of freedom associated with the group factor were also partitioned into two orthogonal planned comparisons, denoted as Group(1) and Group(2). Group(1) compared control group (E3) performance with that of the average of the two experimental groups (E1, E2) to assess whether transfer occurred from TopGun to U-COFT. Group(2) compared performance of E1 with E3 to assess whether added TopGun training produced additional transfer to U-COFT. Initially, both accuracy and speed scores were entered simultaneously into a doubly multivariate MANOVA (Norusis, 1986). To determine how much TopGun training is needed for effective transfer, the U-COFT-based stationary target accuracy scores of

Groups E3 and E1 were compared using the Group(2) orthogonal comparisons mentioned above. To determine if TopGun performance can be used to predict U-COFT performance, correlations between corresponding measures of TopGun and U-COFT performance were computed. To interpret relative sizes of these correlations, within-device reliability coefficients (Cronbach's Alpha) were first calculated separately for TopGun and U-COFT performance. They were calculated by applying Spearman-Brown formula to the average intercorrelation between four performance measures, one for each type of target. These resulted in both actual and maximum possible between-device correlations. To determine how target characteristics affected performance on each device, univariate F-ratios were computed from the full-rank model that included the five independent variables and all interaction terms. Estimates of variance components were made according to formulas derived from expected mean squares, and compared to the total within target variance composed of the sum of three target factor components and three error variance components (Hart & Bradshaw, 1981; Winer, 1971).

h. Trainee Sophistication: Twenty-four soldiers held the 19E (Armor Crewman) Military Occupational Specialty (MOS) with a duty position of either driver or loader. The other 24 soldiers were non-19E MOSs with no tank gunnery experience.

i. Use of Instructional Features: TopGun was programmed to lay the main gun near the target (+/- 5 mil in both elevation and azimuth) and provide the appropriate fire command with embedded tank-to-target distance. Feedback regarding individual round trajectory and location was provided by an explosion graphic superimposed on the target. The game data area on the device provided the tank gunners with the status of the training session (score, ammunition remaining, elapsed stage and game time, gun azimuth and elevation angles, range to target, and gun status).

5. Discussion:

a. Major Findings:

(1) Soldiers' performance improved significantly across the three TopGun training sessions for both accuracy and speed. Session means showed an increase in the number of stationary and moving targets hit and a decrease in the time required to hit them. Improvement was not uniform; accuracy increased more for moving than for stationary targets across sessions, and speed increased more for moving targets than for stationary targets.

(2) The experimental groups displayed significantly better accuracy on U-COFT than did the control group, but only on stationary targets. That is, training transfer was found from TopGun to U-COFT in terms of accuracy (not speed) on stationary targets (not moving targets). The experimental groups also scored significantly more hits on distant targets, but about the same number of hits on close targets as control group soldiers with no prior TopGun training.

(3) The data showed that training transfer was rapid and required only a single TopGun training session to develop for the kinds of stationary targets presented. That is, increasing the number of sessions from one to three produced no corresponding increment in transfer.

(4) TopGun and U-COFT between-device performance correlated significantly for both accuracy and speed. The speed correlation was larger, indicating that U-COFT gunnery speed can be predicted more accurately than U-COFT gunnery accuracy on the basis of corresponding TopGun scores.

(5) Target type was found to influence significantly both the accuracy and speed of gunnery performance demonstrated on TopGun and U-COFT. In terms of gunnery accuracy, both distant and moving targets were more difficult to hit than close and stationary targets. Target movement was found to have a greater effect than distance on the ability of soldiers to record a first round hit on TopGun and U-COFT. The speed of gunnery performance showed a slightly different pattern on the devices. Targets that were moving or distant took longer to hit than targets stationary or close. On U-COFT, target movement had a greater effect than target distance on time to achieve a first round hit. Unlike TopGun speed scores, U-COFT speed scores produced a significant Distance x Movement interaction resulting from the relatively slow speed of first round hits on close, moving targets.

b. Authors' Conclusions:

(1) Both gunnery speed and accuracy on stationary and moving targets improved during TopGun training.

(2) Training transferred from TopGun to U-COFT in terms of gunnery accuracy (not speed) on stationary (not moving) types of targets.

(3) U-COFT performance can be predicted on the basis of TopGun performance, with greater correlation for gunnery speed.

c. Limitations:

(1) The findings apply only to the conditions under which they were demonstrated. That is, M60A3 degraded mode (auxiliary sight) gunnery against single stationary and moving targets from a defensive (stationary) position using the APDS portion of the M105D telescope. What resulted under these conditions may not generalize to other gunnery conditions.

(2) Learning and ceiling effects were probably operating selectively to produce many of the results. The gunners were given 10 trials prior to TopGun training and four practice trials prior to U-COFT testing. As indicated, gunnery proficiency on stationary and close targets (unlike that on moving and distant) started out high (9.1 hits out of 10 targets) and thereafter was artificially restricted by the 10-target maximum ceiling.

d. Considerations: There are distinct differences in how TopGun and U-COFT devices function and these unique differences may have lessened the opportunity to demonstrate transfer of training from TopGun to U-COFT.

6. Related Work:

a. Hart, R. J., & Bradshaw, S. C. (1981). Reliability of estimation for aggregated data: Applications for organizational research (ARI Technical Report 541). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A129 740)

b. Norusis, M. J. (1986). Advanced statistics: SPSS/PC+ for the IBM PC (pp B-142, B-175). Chicago, IL.

c. Wells, R., & Hagman, J. D. (1989). Training procedures for enhancing Reserve Component learning, retention, and transfer (ARI Technical Report 860). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A217 450)

d. Winer, B. J. (1971). Statistical principles in experimental design (2nd ed). New York: McGraw-Hill.

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14. Hoffmam, G. R., & Melching W. H. (1984). Field trials of the MK60 tank gunnery simulator in Armor Institutional Training courses, Volume I: Final Report (ARI Research Report 1381). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A170 939)

1. Topic Keywords: Armor; M60A1; Gunnery; Training Device; MK60; M55 Laser; BAT; AOB; Training Effectiveness; Training Transfer; Gunnery Performance Prediction.

2. Short Summary: This report described two field trials of the Perceptronics Inc. MK60, a part-task tank gunnery device. The field trials assessed (a) training effectiveness of the MK60 for teaching tank gunnery skills, (b) transfer of that training to M60A1 tank performance, (c) validity of the MK60 to predict M60A1 performance of individual soldiers, and (d) the opinions of students and instructors. Field trials were conducted with Armor Officer Basic (AOB) students and with enlisted students in Basic Armor Training (BAT). Two intensities of training were compared to the normal program of instruction. The results revealed that: (a) MK60 performance increased as a direct function of practice, with improvement in speed of achieving target hits and in the consistency of gunner verbal responses, (b) transfer of training from the MK60 to dry-fire and live-fire on the M60A1 tank appeared equal to that of other devices used in gunnery training, (c) the MK60 was not predictive of individual M60A1 performance, and (d) students and instructors considered the MK60 challenging, realistic, and were very favorable toward its use.

3. Performing Organization: Human Resources Research Organization (HumRRO), 1100 South Washington Street, Alexandria, VA 22314.

4. Approach: Experimental

a. Number of Groups: Three groups for Field Trial 1 and 2.

b. Description of Groups:

(1) Field Trial 1:

(a) Group 1: The subjects were 24 AOB students randomly assigned to a high intensity MK60 training group. They completed an MK60 pretest, practiced for about one hour on the MK60 (using training Modules 1 and 2) and for about two hours on the M55 Laser, and completed an MK60 posttest. One to three days later they completed a dry-fire test on the M60A1 tank, followed by a live-fire test the next day.

(b) Group 2: Same as Group 1 except that the AOB students were randomly assigned to a low intensity MK60 training group which practiced on the MK60 using only training Module 1.

(c) Group 3: Same as Group 1 except that the AOB students were randomly assigned to a control group which received no training on the MK60, but spent about three hours of training on Tank Tables I, II, and III (day) using the M55 Laser.

(d) All Groups: The students came from three AOB classes which had received M60A1 conduct of fire training before being tested or trained on the MK60. None had fired the M60A1 tank's main gun. Because AOB trains students in "crews" of four, crews were selected rather than individuals using a table of random numbers. The first two crews were assigned to Group 3, the next two to Group 2, and the last two to Group 1. A student questionnaire was administered at the completion of the live-fire test to gather user opinions about the MK60.

(2) Field Trial 2:

(a) Group 1: Ten BAT students were randomly assigned to a high intensity MK60 training group. They completed two ability pretests (target detection, target tracking) and two MK60 pretests (Test Y followed by Test X), and then practiced for about three hours on the MK60 (using Module 1) with an equivalent amount of time spent in recording, observing, and listening to instructor feedback to another gunner's MK60 performance. After their .22 cal Brewster exercises 15 days later, they practiced for about one hour on the MK60 (using training Module 2) and then completed the two MK60 posttests. One to two days later they were given a dry-fire test on the M60A1 tank, followed one day later (or immediately after the dry-fire test for one company) by a live-fire test on the M60A1.

(b) Group 2: Same as Group 1 except that the BAT students were assigned to a low intensity MK60 training group which practiced on the MK60 using only training Module 1.

(c) Group 3: Same as Group 1 except that the BAT students were assigned to a control group which did not train on the MK60, but spent about eight hours of training on Tank Tables I, II, and III (day) using the M55 Laser instead.

(d) All Groups: The students came from four BAT companies and each had received M60A1 conduct of fire training (two four-hour training periods) before being tested or trained on the MK60. None had fired the M60A1 tank's main gun. A total of 30 students were randomly selected from each company, with all members of each group selected from the same platoon. A student and instructor questionnaires was administered at the completion of the live-fire test to gather user opinions about the MK60.

c. Tests or Trials: A "no treatment" (i.e., no conduct of fire training) control group was not practical; thus, training transfer was relative to current methods rather than absolute.

(1) Field Trial 1: The MK60 pre- posttest (Test Y) consisted of seven main gun engagements selected from the 20 main gun engagements available for training. In Training Module 1, the 20 engagements were clustered (four exercise sets) and sequenced so that the students would practice only one type of engagement at a time. In Module 2, engagements were presented serially. The dry-fire test consisted of eight moving targets which were engaged (ammo announced but not loaded) from four instrumented tanks with AOB instructors serving as the tank commanders (TCs). Each tank contained a videotape camera, placed in the Infrared (IR) signt elbow, to record the sight picture at the time the trigger was pulled. The live-fire test was Tank Table VIA (Department of the Army, 1977).

(2) Field Trial 2: Except for two ability pretests (Melching and Hoffman, 1982), the training and testing materials were similar to those used in Field Trial 1. The MK60 training included a burst-on-target fire adjustment technique presented on a floppy diskette. A second MK60 test (Text X) was also given. For the pretest, it included 10 main gun (six stationary, four moving) engagements. For the posttest, it included seven (four stationary, three moving) engagements. Two different ranges were used for the dry and live-fire tests.

d. Number of Different Types of Measures Used: 3

e. Description of Measures/Ratings: The MK60 performance measures were: (1) announcing "Identified", (2) announcing "On the Way", (3) average score, (4) average seconds, (5) average rounds, (6) average miss (mils), and (7) average hits. The dry-fire measures were: (1) time to acquire (seconds), (2) time to lay (seconds), (3) 1st round lead error (mils), both standard and optimum, (4) 1st round elevation error (mils), (5) 1st round

radial error (mils), standard and optimum, (6) time to adjust (seconds), (7) 2nd round lead error (mils), standard and optimum, (8) 2nd round elevation error (mils), and (9) 2nd round radial error, standard and optimum. The live-fire measures were: (1) percent of rounds scored as hits, (2) percent of rounds scored as misses, and (3) percent of rounds scored as lost.

f. Experimental Setting/Training Context: The research was conducted in an institutional and field setting using a hands-on training and testing approach. For AOB and BAT courses, each group was monitored during M60A1 conduct of fire training, dry-fire testing, and live-fire testing. Technical difficulties were encountered with the cameras which reduced the reliability of some measures associated with dry-fire analyses. Also, score cards for Table IV (main gun firing at stationary and moving targets) were obtainable from BAT students only.

g. Statistical Methods: To assess training effectiveness of the MK60, performance scores were analyzed for pre- posttest differences and for posttest differences among the three groups. Repeated measures analysis of variance (ANOVA) was conducted, as was a repeated measures analysis of covariance (ANOCOVA) using the pretest engagements as covariates. Means were computed for each students' posttest engagement scores, seconds, rounds used, miss mils and hits across the engagements. These averages were then used as the criterion set in a multivariate analysis of variance (MANOVA). To assess transfer of training, the Yates procedure (Kirk, 1968) was used to estimate missing data points for each of the dry-fire variables. The resulting data matrix was used to calculate mean performance for each student. A MANOVA was conducted (a) using the time variables, the first-and second-round elevation errors, and the first and second round lead errors based on standard lead policy, and (b) using the time and elevation data along with lead errors calculated from optimum required leads. To estimate the reliability of the dry-fire scores, intercorrelations among the scores from each engagement (before insertion of estimates for missing data) were calculated for nine of the 13 dry-fire variables. Average intercorrelation was computed (Fisher's r to z transformation) for each dry-fire variable. From these, the Spearman-Brown formula was used to estimate reliability from the eight engagements. To determine the validity of the simulated test for dry-fire variables, correlations between MK60 pre- posttest performance and dry-fire variables were computed. Correlations were also calculated between number of MK60 engagements practiced and dry- fire performance. Means were calculated to assess questionnaire data, with comparisons made between the low and high intensity groups.

h. Stage of Training: AOB and BAT

i. Trainee Sophistication: Inexperienced

j. Incorporation into Program of Instruction (POI): Two MK60 training modules were incorporated into the AOB and BAT POIs. For AOB, Module 1 training occurred during the first four-

hour block of M55 Laser conduct of fire training. Module 2 training occurred during time students would have normally waited to receive training on Tables I-IV. For BAT, Module 1 training occurred during the 10th week and substituted for time normally devoted to training on Tables I, II, and III (day) using the M55 Laser. Module 2 training occurred 15 days later and immediately after the students had received their .22 cal Brewster exercises.

k. User Acceptance or Attitude: The student questionnaire focused on how well they liked MK60 training, its realism, how they would allocate training among several devices, and utility of feedback. The instructor questionnaire focused on problems operating the MK60, its realism. utility of feedback, and how it compared with others devices for teaching gunnery. A five-point rating scale was used with appropriate anchors.

5. Discussion:

a. Major Findings:

(1) Field Trial 1:

(a) There was a significant pre- posttest main effect for each of the seven device performance measures. That is, students across all groups improved their MK60 performance. In none of the ANOVAs calculated was there a significant group by test session interaction which would have signified differential amounts of improvement on the MK60.

(b) ANOCOVA revealed significant group differences for three of the performance scores: announcing "Identified," "On the Way," and engagement score (calculated as a function of time, rounds used, and hit accuracy). For these scores, MK60 groups improved more than the regularly trained group.

(c) A MANOVA (using a composite posttest criterion set) revealed significant group differences. Univariate ANOVAs on mean posttest scores were significant for engagement scores and seconds to complete the engagement. Thus, improvement from pre- posttest was attributable to speed of achieving a hit.

(d) Transfer of training to dry-fire performance revealed no significant group difference. Two of the follow-up ANOVAs suggested group differences in use of 1st round optimum lead and time to adjust. For time to adjust, the MK60 trained groups were faster than the control group. For optimum lead, the high intensity MK60 group was essentially the same as the control while the low intensity group appeared somewhat more accurate.

(e) The reliability of the dry-fire measures was low, the MK60 scores had no validity for predicting M60A1 dry-fire scores, the MK60 test revealed low test-retest reliability, and transfer of training to Table VI live-fire performance was not possible due to questionable data.

(f) In general, AOB students indicated they liked training on the MK60, found it moderately realistic, considered the feedback very helpful, preferred the M55 laser trainer, and desired more MK60 practice than used in the field trial.

(2) Field Trial 2:

(a) Analysis of the seven training engagements and both pre- posttest revealed significant pre- posttest main effect for each measure. That is, students across all groups improved their MK60 performance. For engagement score and seconds, there was a significant test by group interaction indicating differential training improvement (i.e., strong evidence for effects of practice on performance of practiced items).

(b) Analysis of 10 engagements administered during the pre- posttest revealed significant group differences for five of the six performance measures analyzed. A significant increase in targets hit was not indicated. For engagement score, there was significant test by group interaction indicating differential improvement in performance. ANOCOVA results showed significant group effects for announcing "On the Way", engagement score, seconds, and hits. These results illustrated the transfer of practice effects from one set of MK60 engagements to another.

(c) Analysis of posttest only engagements which were novel to all students revealed that the training groups were significantly different for engagement score and for seconds. Also, the groups differed significantly on target hits and on announcing "On the Way." Again, MK60 practice appeared to improve MK60 performance.

(d) A MANOVA (using a composite posttest criterion set) revealed significant group difference. Univariate ANOVAs on mean posttest scores were significant for score, seconds, miss mils, and hits.

(e) Correlations between the three ability pretest scores (detection, tracking time, tracking error) and the MK60 student average scores revealed that only tracking time was consistently related to performance.

(f) Transfer of training to dry-fire performance revealed no significant group difference. Separate ANOVAs calculated on each criterion measure were also not significant. No effects or trends were found on means of the unstandardized dry-fire scores for the three training groups.

(g) Transfer of training to live-fire performance (Table VI) revealed no significant group difference on percent of hits. The correlation between MK60 pretest score and percent of hits during live-fire indicated that the MK60 was not predictive of M60A1 live-fire performance.

(h) There appeared to be little relationship across the MK60, ability tests, and dry-fire domains. Again, the MK60 scores appear to have little validity for predicting dry- fire performance.

(i) BAT instructors reported that they experienced very few problems with the device, thought the MK60 provided extremely realistic practice, viewed the feedback provided to be very useful, and strongly favored the addition of the device to current training.

c. Authors' Conclusions:

(1) The analysis of the MK60 pre- posttests supports the conclusion that MK60 performance improves with practice. This improvement is due primarily to the speed of achieving target hits. The more students practice, the faster they achieve a target hit, and consequently, the higher their engagement score.

(2) In addition to improvements in engagement scores, there is also evidence from both AOB and BAT evaluations that the MK60 can be used to reinforce procedural aspects of tank gunnery.

(3) Given that the MK60 was substituted for M55 Laser training, the "no difference" results for the dry-fire and live-fire assessments mean the MK60 is not detrimental to learning.

(4) The test-retest reliability of the MK60 is weak and the predictive validity of MK60 scores for dry-fire and live-fire performance is poor.

(5) The MK60 appears to have a very positive acceptance by students and instructors as a device for teaching M60A1 tank gunner skills. It appears that the repeated practice reinforces procedural responses and emphasizes speed of responding.

d. Limitations:

(1) In both Field Trials, a MANOVA using a composite posttest criterion set revealed significant group differences. Although composite measures possess greater validity, their reliabilities are difficult to assess because they combine many different elemental skills which may themselves be uncorrelated with each other. By being based on such diverse elements, their use opens the door for potential interpretation problems as to the transfer of specific skills to dry or live-fire.

(2) The test-retest method of assessing reliability assumes no significant events have intervened between testing occasions to alter the relative order of tested subjects. The assumption that no conditions other than MK60 training occurred to cause a change in relative order is incorrect. Students were given their two posttests on the same day after they had just completed their .22 cal training. Also, repeated testing serves to increase statistical power, often by increasing reliability.

(3) MK60 functional deficiencies were reported by the authors and these device deficiencies, especially with respect to performance scoring, may have affected the results.

6. Related Work:

a. Department of the Army (1977). Tank gunnery for M60, M60A1, M60A1(AOS), and M48A5 tanks (Field Manual 17-12-2). Washington, DC: Author.

b. Hoffman, R. G., & Melching, W. H. (1984). Field trials of MK60 tank gunnery simulator in armor institutional training courses. Volume II: Training and testing materials (ARI Research Note 84-60). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A138 572)

c. Kirk, R. E. (1984). Experimental design: Procedures for the behavioral sciences. Belmont, CA: Brooks/Cole.

d. Melching, W. H., Campbell, R. C., & Hoffman, R. G. (1982). Target scenario specifications for use with the MK60 tank gunnery device (HumRRO Research Product RP-MTRD (KY)-82-4). Fort Knox, KY: Human Resources Research Organization.

e. Melching, W. H., & Hoffman, R. G. (1982). Development of training, testing and questionnaire materials used in institutional field trials with the MK60 tank gunnery device MK60 tank gunnery device (HumRRO Interim Report). Fort Knox, KY: Human Resources Research Organization.

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15. Hoffman, R. G., & Witmer, B. G. (1989). Development of a Unit-Conduct of Fire Trainer (U-COFT) test of M1 gunner proficiency (ARI Technical Report 859). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A219 045)

1. Topic Keywords: Armor; M1 Tank; Tank Gunnery; Simulators; U-COFT; Test and Evaluation; Performance Test; Test Construction.

2. Short Summary: A test of M1 tank gunnery proficiency was prepared for the Unit-Conduct of Fire Trainer (U-COFT), based on an analysis of Tank Table (TT) VIII engagement parameters. The test consisted of four U-COFT exercises comprising 23 different moving and stationary engagements against moving and stationary, single and multiple targets. A special set of instructions were developed for Instructors/Operators (I/Os) for testing. Hit rate was identified as the most appropriate composite measure of tank gunnery performance. Instructions were prepared for calculating hit rate for each engagement and for the entire test. Additional measures were identified for supplementary analyses of gunnery performance. They included (a) firing rate, (b) hit probability,

(c) average opening time, (d) average miss distance, and (e) average numbers of classification and system management errors. The test should facilitate integration of gunnery research, thus increasing knowledge of tank gunnery performance requirements.

3. Performing Organization: U.S. Army Research Institute for the Behavioral and Social Sciences, ARI Field Unit - Fort Knox, Fort Knox, KY 40121-5620.

4. Approach: Analytical

a. Number of Different Types of Measures Used: 7

b. Description of Measures/Ratings: The U-COFT test of M1 tank gunnery proficiency consists of four exercises from reticle aim groups five and six of the TC/gunner matrix. The exercises were selected to correspond to conditions that occur in TT VIII. The exercises do not replicate TT VIII tasks exactly, but they represent all TT VIII conditions in somewhat different sequences and combinations. Each exercise included from four to ten engagements. Three exercises (34611, 34633, and 34622) were selected from reticle aim group six, and one (31563) from reticle aim group five. Two engagements in exercises 34611 and 34622 were modified to increase their correspondence with the exercises comprising TT VIII. One engagement from each exercise was changed to a Nuclear, Biological, Chemical (NBC) engagement by requiring the crews to wear protective masks. In the other engagement, the TC was required to fire the main gun without the gunner's assistance to simulate a three-man crew. The composite measure of U-COFT gunnery proficiency is called hit rate. It is calculated for the number of targets in each of 23 contributing engagements and adjusted for friendly target hits. Hit rate is defined as: Hit Rate (hits/time) equals Hit Proportion (hits/rounds) multiplied by Fire Rate (rounds/time). Hit rate is calculated for each engagement from data on U-COFT printouts on rounds fired, hits, and time. Overall hit rate is calculated from the weighted averages for firing rate and hit probability, where engagement firing rates and hit probabilities are weighted by the number of targets in the engagements. The six additional measures identified for supplementary analyses of tank gunnery performance included (a) firing rate, (b) hit probability, (c) average opening time, (d) average miss distance, (e) average numbers of classification (target acquisition) errors, and (f) average number of system management errors.

c. Experimental Setting/Training Context: Preparation of the one hour test involved four activities. First, U-COFT exercises were selected to represent the domain of conditions defined by M1 Tank Table VIII. Second, detailed administration procedures were prepared and a test administrator's script composed. Third, a test administrator's orientation guide was prepared outlining the general "dos and don'ts" of performance testing. The fourth and final activity was the selection of performance measures and development of scoring instructions.

d. Use of Instructional Features: A set of standardized administration procedures had to be followed, which included verbatim reading of instructions at the start of each exercise. Test procedures emphasized testing requirements rather than usual U-COFT training needs. For example, the I/Os were not allowed to provide feedback or coaching during testing, and switch setting instructions were provided only at the start of each exercise.

5. Discussion:

a. Major Findings:

(1) The U-COFT test, composed of four U-COFT exercises comprising 23 different moving and stationary engagements against both moving and stationary, and single and multiple targets, represented the known domain of M1 gunnery conditions.

(2) Special instructions developed for U-COFT I/Os to follow instead of using their routine U-COFT training procedures ensures consistency of test administration.

(3) Hit rate was identified as the most appropriate composite measure of gunnery performance, with instructions prepared for calculating hit rate for each engagement in the test and for calculating hit rate for the test as a whole.

(4) Additional measures identified for supplementary analyses of performance included firing rate, hit probability, average opening time, average miss distance, and average number of classification and system management errors.

b. Authors' Conclusions: The U-COFT test should facilitate the ability to integrate research in gunnery and thereby increase the understanding of performance requirements in tank gunnery.

c. Limitations: The test was designed to meet several constraints: (a) one hour for testing, thereby limiting the number of U-COFT exercises to four, (b) test procedures should require only one I/O, thereby restricting the source of performance measures to the U-COFT printouts, (c) only complete U-COFT exercises could be used since partial exercises are difficult to run on U-COFT and lead to administration errors (Graham, 1986), and (d) the test would be administered only to persons who are already familiar with U-COFT.

d. Considerations: Until issues of reliability, validity and norming are addressed, this test should be limited just to research applications. The scoring procedures are cumbersome and not considered practical for routine use by units in training.

6. Related Work:

a. Department of the Army (1985). Tank combat tables M1 (Field Manual 17-12-1). Washington, DC: Author.

b. Du Bois, R. S. (1987). The M1 Unit-Conduct of Fire Trainer (U-COFT) as a tank gunnery testing device: A psychometric evaluation. Unpubl hed master's thesis, Western Kentucky University, Bowling Green, KY.

c. General Electric (1985). Instructor's utilization handbook for the M1 Unit-Conduct of Fire Trainer (U-COFT) (Vol.1). Orlando, FL: Naval Training Equipment Center.

d. Graham, S. E. (1986). The Unit-Conduct of Fire Trainer (U-COFT) as a medium for assessing gunnery 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)

e. Smith, M.D., & Hagman, J. D. (1992). Predicting Table VIII tank gunnery performance from M-COFT hit rate and demographic variables (ARI Technical Report 955). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A254 580)

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16. Hughes, C. R., Butler, W. G., & Sterling, B. S (1987). Tank gunnery, written aptitude tests, and the importance of training (TRAC-WSMR-TEA-32-87). White Sands Missile Range, NM: U.S. Army TRADOC Analysis Command. (AD B118 521)

1. Topic Keywords: Armor; M1 Tank; Tank Gunnery; Simulators; U-COFT; Sustainment; Training Effectiveness; Prediction; ASVAB.

2. Short Summary: This study was a follow-up to the M1 Unit-Conduct of Fire Trainer (U-COFT) post-fielding training effectiveness analysis (PFTEA). The purpose was to assess the impact of unit training and the soldier Armed Forces Vocational Aptitude Battery (ASVAB) scores on Tank Table (TT) VIII performance. Six U.S. Army Europe (USAREUR) M1 tank battalions participated in the M1 U-COFT PFTEA; 347 tank crews from these battalions had completed TT VIII. Unit training data were available for 333 of these tank crews in the 24 armor companies evaluated. In addition, comparable ASVAB scores were available for 110 tank commanders (TCs) and 297 gunners. The results revealed that (a) high TC and gunner aptitude scores had little or no correlation with performance on TT VIII, and (b) the amount of unit training had a larger impact than aptitude scores on TT VIII performance. These results support what has been found in other studies; that is, training can overcome the differences reflected by aptitude scores in a soldier's ability to perform his combat mission.

3. Performing Organization: U.S. Army TRADOC Analysis Command, White Sands Missile Range (TRAC-WSMR), NM 88002-5502.

4. Approach: Analytical

a. Number of Groups: 1

b. Description of Groups: The subjects were 333 M1 tank crews from six USAREUR battalions that had fired TT VIII as part of the U-COFT PFTEA. For this group, comparable ASVAB scores (using 1984 norms) were available for 110 TCs and 297 gunners.

c. Tests or Trials: The performance criterion was a special TT VIII which each tank crew fired as part of the U-COFT PFTEA.

d. Number of Different Types of Measures Used: 3.

e. Description of Measures/Ratings:

(1) TT VIII: TT VIII measures were (a) first run total score, (b) probability of hit (PHIT), (c) probability of first round hit (PFRHIT), and (d) average opening time. Opening time was defined as the time from when the tank is first exposed to the target until it fires its first round. In addition to these data, units provided the (a) number of main gun rounds fired by each crew during TT VI and VII (pre-qualification rounds), (b) TC and gunner time together in months, and (c) visibility and weather conditions for each crew's day and night TT VIII firing.

(2) Unit Gunnery Training: All six battalions in the U-COFT PFTEA provided crew rosters, training schedules, and M1 U-COFT training records on a monthly schedule to a team from the Directorate of Evaluation and Standardization (DOES), USAARMS. Data on the amount of training were based on interviews conducted by DOES with battalion commanders, S-3s, and master gunners.

(3) ASVAB: The ASVAB analysis was conducted using TC and gunner scores obtained from the Defense Manpower Data Center, Monterey, CA. The ASVAB is a multiple-choice test containing 10 subtests. Four subtests are combined to form the Armed Forces Qualification Test (AFQT), which is considered a general measure of trainability and the primary criterion for enlistment. Other subtest combinations are used in occupational classification. Two of these, along with AFQT, were used in this analysis. The CO (combat) and GM (general mechanical) composites were used because they address the types of skills needed in tank gunnery.

f. Experimental Setting/Training Context: Crew training was conducted in each unit's training environment. Six M1 tanks were made available for the special TT VIII, along with access to the regular TT VIII firing range at Grafenwoehr, Germany. First run TT VIII scores were obtained from the Training Analysis Division, Seventh Army Training Command (7th ATC), which maintains a data base of all TT VIII firings at the Grafenwoehr Training Area.

g. Statistical Methods: The extent of the relationship between each variable and TT VIII performance was evaluated in terms of a Pearson product-moment correlation coefficient. All available data were combined in multiple regression equations to account for as much of the variation in TT VIII average opening

times and total scores as possible. Variables in the equations included amount of unit training, TT VIII weather and visibility, TC and gunner time together, number of pre-qualification rounds fired, TC and gunner ASVAB scores, and U-COFT matrix progress.

5. Discussion:

a. Major Findings:

(1) Gunnery classes, hands-on training in the motor pool, and U-COFT matrix progress were most highly related to total scores on TT VIII. Classroom and motor pool training were also related to PHIT on TT VIII.

(2) Gunnery classes, motor pool hands-on training, U-COFT matrix progress, TCPC, and TCGST were significantly related to average opening times on TT VIII. The relationships were significant, though each training type accounted for less than 10% of the total variation in TT VIII performance.

(3) Except for a significant correlation between a TC's AFQT score and his crew's average opening time on TT VIII which was in the wrong direction (longer average opening time), all correlations between TT VIII performance and the ASVAB scores for both the TCs and gunners were not statistically significant.

(4) A TT VIII task performed under degraded conditions (computer and laser rangefinder (LRF) failure) failed to support the expectation that AFQT differences might have an effect on TT VIII performance. None of the correlations with TC and gunner AFQT scores was significant statistically.

(5) There were significant differences between the performance of crews with officers and enlisted TCs. Officer had better total TT VIII score and probability of first round hit, but not for probability of hit or average opening time.

(6) Multiple regression equations revealed that, when unit training data are already in the equation, adding ASVAB scores improves prediction very little. On the other hand, when ASVAB scores are already in the equation, adding unit training data drastically improves prediction. The equations also showed that many uncertainties influence the performance of a particular crew during TT VIII gunnery.

b. Authors' Conclusions: Training appears to have a larger impact on TT VIII than those TC or gunner abilities reflected by ASVAB scores. That is, adequate training can overcome mental aptitude differences in preparing soldiers for combat missions.

c. Limitations:

(1) The training data were available only down to the company level; that is, the data assume that all crews within a company received the same amount of training.

(2) The training data were based largely on interviews with unit trainers, rather than observation of on-going training.

(3) The training data reflected only the amount of training, not its quality.

d. Considerations:

(1) Live-fire performance tends to be very unreliable because of measurement difficulties and the nature of the firing tasks. Performance on any single engagement is, at best, only a rough indicator of proficiency (Hoffman, 1989).

(2) There are several important variables not included in the regression equation (e.g., quality of training, education level, armor experience, morale, and reliability of TT VIII).

6. Related Work:

a. Butler, W. G., et al (1982). Training Developments Study - M1 (ABRAMS) tank Unit-Conduct of Fire Trainer training effectiveness analysis (TRASANA-TEA-11-82). White Sands Missile Range, NM: U.S. Army TRADOC System Analysis Activity. (AD B954 521L)

b. Hoffman, R. G. (1989). Description and prediction of Grafenwoehr M1 Table VIII performance (Technical Report 837). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD B136 331)

c. Hughes, C. R., Butler, W. G., Sterling, B. S., & Berglund, A. W. (1987). M1 Unit-Conduct of Fire Trainer post-fielding training effectiveness (TRAC-WSMR-TEA-16-87). White Sands Missile Range, NM: U.S. Army TRADOC Analysis Command. (AD B113 298)

d. Scribner, B. L., Smith, D. A., Baldwin, R. H., & Phillips, R. L. (1986). "Are smart tankers better?" Armed Forces and Society, Vol. 12, No. 2, Winter.

e. Wallace, J. R. (1982). The Gideon criterion: The effects of selection criteria on soldier capabilities and battle results (USAREC Research Memorandum 82-1). Fort Sheridan, IL: U.S. Army Recruiting Command.

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17. Hughes, C. H., Butler, W. G., Sterling, B. S., & Berglund Jr, A. W. (1987). M1 Unit-Conduct of Fire Trainer post fielding training effectiveness analysis (TEA-16-87). White Sands Missile Range, NM: U.S. Army TRADOC Analysis Command (TRAC-WSMR). (AD B113 298)

1. Topic Keywords: Armor; M1 Tank; Tank Gunnery; Simulators; U-COFT; Sustainment; Training Effectiveness; Prediction; ASVAB.

2. Short Summary: The M1 Unit-Conduct of Fire Trainer (U-COFT) post field training effectiveness analysis (PFTEA) was conducted to (a) determine the effectiveness of the U-COFT in sustaining gunnery proficiency in a unit training environment, (b) examine the capability of the U-COFT to predict crew performance on Tank Table (TT) VIII, (c) determine the effects of U-COFT training and pre-qualification firing on TT VIII performance, and (d) examine the effects of other types of unit training and the Armed Forces Vocational Aptitude Battery (ASVAB) scores of tank commander (TC) and gunner on TT VIII performance. Six M1 battalions from the U.S. Army Europe (USAREUR) participated in the PFTEA. Five of these battalions had received and conducted training with the M1. The sixth, the "non U-COFT" battalion, received U-COFT after data collection was completed. The results revealed that (a) U-COFT made a very substantial contribution to the sustainment of tank gunnery skills of those crews whose matrix coordinate achievement was sufficiently high, (b) U-COFT training measures and TT VIII performance were related, but those relationships were not strong enough to allow training on U-COFT to be used as an absolute predictor of TT VIII performance, (c) crews who trained on the U-COFT but did not fire TT VI performed better on average than those crews without U-COFT training, even though the latter crews fired the additional TT VII, and (d) unit gunnery training has more of an impact on TT VIII performance than the ASVAB scores of the TC and gunner.

3. Performing Organization: U.S. Army TRADOC Analysis Command, White Sands Missile Range (TRAC-WSMR), NM 88002-5502.

4. Approach: Experimental

a. Number of Groups: Part I: 3 groups; Part II: 2 groups.

b. Description of Groups: The subjects were M1 tank crews from six USAREUR battalions who had fired their unit's regular TT VIII for qualification. Five of these battalions had trained on the U-COFT while one (non U-COFT battalion) received its U-COFTs after data collection was completed.

(1) Part I: To examine the interactive effects of U-COFT training and main gun pre-qualification firing on TT VIII, the six battalions were divided into three groups. The non U-COFT battalion, which fired TT VI and VII, constituted Group I (N=56); three U-COFT battalions which fired only TT VII comprised Group II (N=174); and two U-COFT battalions that fired TT VI and VII composed Group III (N=117). TT VI normally involves firing 12-15 main gun rounds while TT VII involves firing about 20 rounds.

(2) Part II: To evaluate the sustainment of tank gunnery skills, 15 crews that had remained together since their unit's TT VIII gunnery (about 90 days earlier) were selected from each of the six battalions to fire a special TT VIII. These crews were selected using a stratified random sampling procedure designed to preserve the proportion of distinguished, superior, qualified, and unqualified crews that occurred at each unit's prior gunnery.

c. Tests or Trials: The criterion was a special TT VIII, with each crew engaging the same number of day and night tasks as it engaged for its regular TT VIII.

d. Number of Different Types of Measures Used: 4.

e. Description of Measures/Ratings:

(1) Pre-gunnery Evaluation: This evaluation comprised a U-COFT test together with written surveys, questionnaires, and interviews with battalion leadership, trainers, and a sample of armor crewmen. The U-COFT test consisted of 11 engagements from three U-COFT exercises selected by the U.S. Army Armor School (USAARMS). Four U-COFT engagements were matched to four specific engagements on TT VIII. A crew's U-COFT training was measured in terms of its (a) matrix achievement and (b) the number of U-COFT exercises it had fired. These data were taken from printouts obtained from the U-COFT computer.

(2) TT VIII: TT VIII performance was measured in terms of total score, percentage of first round hits, and opening time. Opening time was defined as the elapsed time from exposure of the M1 tank to the target until the tank fires its first round. All TT VIII data were gathered from the crew's first run.

(3) Unit Gunnery Training: Unit gunnery training data were gathered by a team from the Directorate of Evaluation and Standardization (DOES), USAARMS. The DOES team periodically visited each unit and interviewed members of the command staff responsible for unit training. The team compiled a history of all gunnery training conducted by each unit. The information is accurate down to company level; that is, data show the training each company conducted but not each crew within the company.

(4) ASVAB: The ASVAB analysis was conducted with scores obtained from the Defense Manpower Data Center, Monterey, CA. The ASVAB is a multiple-choice test containing 10 subtests. Four subtests are combined to form the Armed Forces Qualification Test (AFQT), which is considered a general measure of trainability and the primary criterion for enlistment. Other subtest combinations are used in occupational classification. Two of these, along with AFQT, were used in this analysis. The CO (combat) and GM (general mechanical) composites were used because they address the types of skills needed in tank gunnery.

f. Experimental Setting/Training Context: Six M1 tanks were made available for firing the special TT VIII, along with access to the regular TT VIII range at Grafenwoehr, Germany, by the Seventh Army Training Command (7th ATC). The first day after their arrival on the range, the crews boresighted the tanks and were given a multiple choice survey concerning the training they received since their previous TT VIII gunnery. The following day each crew completed an accuracy screening test using three main gun rounds to verify the tank they were to fire was functioning properly, and conducted their TT VIII day and night runs.

g. Statistical Methods: Descriptive statistics (means, percents) were used to compare the results of the two TT VIII firings with U-COFT test performance. Statistical t-tests and linear trend analysis were used to make direct comparisons between the five battalions that trained on the U-COFT and the one non U-COFT battalion, in terms of TT VIII and U-COFT test performances. T-tests were also used to examine the interactive effects of U-COFT training and pre-qualification main gun firing on TT VIII performance. Pearson product moment correlations were used to compare the results of a crew's U-COFT performance and their performance on similar tasks on TT VIII, and to determine the effects of various types of unit gunnery training and the ASVAB scores of the TC and gunner (AFQT, CO, and GM composite scores) on TT VIII performance.

h. Stage of Training: Sustainment training.

6. Discussion:

a. Major Findings:

(1) Comparison of results from the two TT VIII firings found that 62% of the crews who had not reached reticle aim group three in the U-COFT training matrix had lower overall scores on the second firing than they achieved on the first, and 41% had scores that were 100 points or more below their first scores.

(2) Using the same comparison as above, 74% of those crews who had reached or exceeded reticle aim group three had higher scores on the second TT VIII, and 45% gained 100 points or more.

(3) Comparison of battalions that trained or did not train on the U-COFT found that crews with U-COFT training had significantly faster opening times for offensive and defensive tasks on TT VIII. For offensive tasks, the U-COFT trained crews fired their first round approximately one and one-half seconds faster than the other crews, and achieved the same percentage of first round hits (approximately 80%).

(4) A significant linear trend was found when the sample was divided into crews without U-COFT training, crews with U-COFT training who had not reached reticle aim group three, and crews with U-COFT training who had reached or exceeded group three.

(5) Direct comparisons between results of a test of the crew's U-COFT performance and their performance on similar tasks on the live-fire TT VIII found no significant relationships.

(6) Crews who trained on U-COFT but did not fire TT VI performed better than crews without U-COFT training, even though the latter crews fired the additional table. However, the crews that received U-COFT training and fired TT VI and VII performed better than crews with U-COFT training who did not fire TT VI.

(7) Three measures of unit gunnery training related significantly with TT VIII total score and average opening time; amount of classroom training, amount of "motor pool" training (boresighting, preparing stations, manipulation exercises, and tracking exercises), and crews' U-COFT matrix achievement.

(8) The number of tank crew gunnery skills tests (TCGST) and tank crew proficiency course (TCPC) exercises correlated significantly with average opening time on TT VIII.

(9) No significant relationships were found between TC and gunner AFQT, CO and GM composite scores and performance on TT VIII. One exception was the AFQT scores and average opening time of the TCs, but it was in the wrong direction (i.e., the higher the AFQT score the longer the opening time).

b. Authors' Conclusions:

(1) The U-COFT is an effective gunnery training device when used in such a way as to allow crews to progress into the higher levels of the training matrix.

(2) U-COFT matrix progress and amount of U-COFT training relates significantly to gunnery performance on TT VIII. However, the relationships are not sufficient to allow use of the U-COFT training measures as predictors of TT VIII performance.

(3) Measures of unit gunnery training (e.g., motor pool, classroom, number of TCGST and TCPC) relate significantly to TT VIII results whereas ASVAB scores of the TC and gunner do not.

c. Limitations:

(1) Live-fire performance tends to be unreliable because of measurement difficulties and the nature of the firing tasks. Performance on any single engagement is, at best, only a rough indicator of proficiency (Hoffman, 1989).

(2) The U-COFT test contained only 11 engagements from three U-COFT exercises, and test reliability was not reported. Also, there was no significant relationship found between the crew's U-COFT performance and their performance on similar tasks on the live-fire TT VIII.

(3) Whether the stratified random sampling procedure selected tank crews which were equivalent in gunnery performance prior to firing the second TT VIII is not certain.

(4) The sample of crews from the non U-COFT battalion was too small (N=14) to provide definitive results.

(5) An in-depth analysis of units' home station gunnery training received prior to the second TT VIII was not attempted. The analysis assumes that each crew within the companies received the same amount of training as other crews in those companies.

(6) The crews (six battalions) used the same six tanks for live-firing the special TT VIII, rather than their own tanks.

d. Considerations:

(1) A U-COFT pretest of gunnery proficiency would have determined whether completing an increased number of U-COFT exercises or attaining a higher reticle aim group level in the U-COFT matrices was the result of more proficient TCs and gunners.

(2) The data on the non-U-COFT battalion revealed that eight of the 14 crews that fired the special TT VIII had higher scores, with four crews gaining more than 100 points. Thus, previous TT VIII firing, crew (TC and gunner) stabilization, and unit gunnery training (classroom training, motor pool training, TCGST, TCPC, etc.) are variables which tend to interact (aside from U-COFT training) to produce positive TT VIII results.

6. Related Work:

a. Butler, W. G., Reynolds, M. J., Kroh, M. Z., & Thorne, H. W. (1982). Training developments study--M1 (Abrams) Tank Unit-Conduct of Fire Trainer (TRASANA TEA-11-82). White Sands Missile Range, NM: U.S. Army TRADOC System Analysis Activity. (AD B954 521)

b. Hoffman, R. G. (1989). Description and prediction of Grafenwoehr M1 Table VIII performance (ARI Technical Report 837). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD B136 331)

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18. Kraemer, R. E., & Smith, S. E. (1990). Soldier performance using a part-task gunnery device (TOPGUN) and its effects on Institutional-Conduct of Fire Trainer (I-COFT) proficiency (ARI Research Report 1570). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A227 403)

1. Topic Keywords: Armor; M1 Tank; Gunnery; Training Devices; TOPGUN; I-COFT; U-COFT; Training Transfer; Soldier Performance.

2. Short Summary: The use of TOPGUN as a tank gunnery device was examined in three experiments. Soldiers were randomly assigned to one of three groups; recreational/free-play (REC), formal/structured (FORM), or no training group (NTG). Device-based performance improvement was examined by comparing pre- and posttest scores on TOPGUN using six measures of gunnery accuracy and speed. Transfer of training to the Institutional-Conduct of Fire Trainer (I-COFT) was examined during the third experiment. The results revealed that (a) experienced and inexperienced soldiers learned tank gunnery skills on TOPGUN, (b) performance improvements on TOPGUN were not significantly different using either a free-play or structured approach, (c) the gunnery skills

of qualified M1 crewman significantly improved from TOPGUN pretest to posttest, but soldiers trained did not perform significantly different from those in the NTG on any of the six measures to indicate transfer to I-COFT, and (d) the soldiers' attitudes about TOPGUN were positive.

3. Performing Organization: U.S. Army Research Institute for the Behavioral Sciences, ARI Field Unit - Fort Knox, Fort Knox, KY 40121-5620.

4. Approach: Experimental

a. Number of Groups: 3

b. Description of Groups: In Experiments 1 and 2, each group contained 16 soldiers. Eight soldiers were noncommissioned officers (NCOs) whose Military Occupational Specialty (MOS) was Cavalry Scout (MOS 19D), and eight were 2nd lieutenants waiting to attend the Armor Officer Basic Course (AOBC). In Experiment 3, each group had 12 qualified MOS 19K (M1 tank crewman) gunners.

c. Tests or Trials:

(1) Subjects in FORM Group: In Experiments 1 and 2, soldiers were familiarized with TOPGUN, pretested, given two hours of structured training, posttested, and given a Subject Opinion Questionnaire. In Experiment 3, they were familiarized with I-COFT and TOPGUN, pretested on both devices, given nine hours of structured TOPGUN training over four days, posttested on both devices, and given a Subject Opinion Questionnaire.

(2) Subjects in REC Group: Same as above, except the soldiers received recreational (REC) mode of training on TOPGUN.

(3) Subjects in NTG Group: Same as above, except the soldiers received no TOPGUN training.

(4) Both Groups: In Experiments 1 and 2, all soldiers were pre- and posttested on TOPGUN using the same number and type of engagements. In Experiment 3, all were pre- and posttested on I-COFT and TOPGUN using the same number and type of engagements. Because subjects did not significantly differ on any of the six performance measures, the first two experiments were combined to increase sample size and overall statistical power.

d. Number of Different Types of Measures Used: 6

e. Description of Measures/Ratings: The accuracy measures were: (1) percentage of hits (hits/rounds fired), (2) percentage of targets hit (hits/targets presented), (3) percentage of first round hits (hits with first round/targets attempted), and (4) rounds per target (rounds fired/targets attempted). The two speed measures were: (1) hit rate (hits x 60/total exposure time for targets attempted) and (2) fire rate (total rounds fired x 60/total exposure time for targets attempted).

In Experiments 1 and 2, 30 highly difficult engagements were selected for the TOPGUN pre- and posttest. The domain of gunnery engagements were identified using a 3^3 factorial, 9 x 9 quasi-latin square design (Cochran & Cox, 1957). Approximately 15 minutes were needed to administer the tests. In Experiment 3, the domain of engagements was used to develop six alternate forms of TOPGUN pre- and posttests with each alternate form containing 84 engagements. The I-COFT pre- and posttests were selected from the list of training exercises available on the device, and based on comparable test target engagements using TOPGUN. The I-COFT pre- and posttests consisted of four I-COFT exercises (40 target engagements) and required about one hour to administer.

f. Experimental Setting/Training Context: The research was conducted in an institutional setting using a hands-on approach to training and testing. Standardized instructions were used for TOPGUN and I-COFT testing and TOPGUN training. Experiments 1 and 2 were conducted during two 1-day periods using six research assistants (RAs) assigned to three of 18 TOPGUNs. All soldiers received 15 minutes of M1 conduct-of-fire classroom instruction, 10 minutes of device familiarization and supervised practice, and 30 minutes to complete TOPGUN pre- posttests. Soldiers in the two training groups received two hours of TOPGUN training by the RAs. Experiment 3 was conducted over 12 weeks with 12 soldiers every two weeks. All soldiers received 10 minutes of TOPGUN familiarization and supervised practice and one hour to complete the I-COFT and TOPGUN pre- posttests. The I-COFT tests were administered by six qualified instructor/operators (I/Os). The six RAs used in the first two experiments tested-trained-tested two soldiers simultaneously using two TOPGUN devices. Soldiers in the two training groups received about nine hours of TOPGUN training over four consecutive days.

g. Statistical Methods: A three-step approach was used for data analysis, using procedures from the Statistical Package for the Social Sciences (SPSS/PC+, 1988). First, pre- and posttest data were analyzed using a multivariate analysis of variance (MANOVA) to examine: (1) if soldiers' scores on the six measures improved from pretest to posttest, and (2) if there were any group differences based on the difference scores from pretest to posttest. Second, a multivariate analysis of covariance (ANCOVA) was calculated to examine group differences on the posttest performance measures using the pretest measures as covariates. Univariate follow-ups and planned comparisons were conducted as indicated by significant MANOVA results. Third, descriptive statistics were used to analyze the questionnaire data.

h. Trainee Sophistication: Novices for Experiments 1 and 2; qualified M1 gunners for Experiment 3.

i. User Acceptance or Attitude: Measures of attitude and TOPGUN training realism were obtained using a 5-point scale to indicate extent of agreement. The first 16 items focused on how well soldiers liked training on TOPGUN, while the next 14 items focused on soldiers' perceived realism of the device.

j. Use of Instructional Features: Soldiers in the FORM group were TOPGUN trained using a structured, easy-to-difficult approach. Targets were programmed to appear within a 5-mil radius of the gunner's sight reticle. Gunners were allowed only two rounds per target before the engagement ended, about 16 seconds to complete a single engagement, and about 28 seconds to complete a multiple engagement. Included in these times was a five second delay for loading a second round. Soldiers in the REC group were trained using a free-play, more difficult strategy whereby targets were randomly generated by the computer. The number and location of targets were random as was the amount of time allowed to complete an engagement. An engagement ended only when the target(s) were hit. Subsequent engagements were based on the computer program and if ammunition was still available. Soldiers in both training groups were given initial fire commands and laid in the target area by a pseudo TC. Also, the game data area on the device provided the gunners with the status of the training session (score, ammunition remaining, elapsed stage and game time, gun azimuth and elevation angles, range to target, and gun status). Feedback on round accuracy was provided by the explosion graphic superimposed on the target by the system.

5. Discussion:

a. Major Findings

(1) For experiments 1 and 2 combined, a significant improvement in performance was found from TOPGUN pretest to posttest on five of six measures. However, no difference was found between the two groups and the NTG or between the groups trained using the FORM or REC mode. The effects of pretest and hands-on training were sufficient to produce a training benefit.

(2) Examination of group means showed that all groups improved their gunnery performance scores from pre- to posttest. Although the two experimental groups showed greater improvement, improvement by the NTG resulting from pretest practice made it impossible to detect significant group differences.

(3) For experiment 3, significant improvement in gunnery proficiency was found from TOPGUN and I-COFT pretest to posttest on all six measures. The MANOVA for the TOPGUN Training Group by pretest-posttest interaction was not significant. However, by combining the two training groups and comparing those soldiers performance with the NTG, the TOPGUN pre- to posttest performance was significant for five of six measures i.e., the performance of soldiers who trained on TOPGUN for nine hours improved more than those who did not receive the added training. Similar results also were found for the multivariate ANCOVA on four posttest performance measures using the pretest measures as covariates.

(4) In terms of transfer, soldiers trained on TOPGUN did not perform significantly different from those in the NTG on any of the six measures. Also, there were no significant differences in I-COFT performance between the two training groups.

b. Authors' Conclusions:

(1) In the first two experiments, although soldiers had no previous gunnery experience, minimum TOPGUN familiarization and hands-on practice significantly improved their performance from pre- to posttest on all six performance measures.

(2) In the third experiment, qualified M1 tank gunners significantly improved their performance from pre- to posttest. When the two training groups were combined, they demonstrated greater improvement compared to those in the control group.

(3) There were no significant differences between the two training groups combined and the NTG group on the criterion measures; i.e., training on TOPGUN did not transfer to I-COFT.

c. Limitations:

(1) In all 3 experiments, sample size was insufficient to detect differences between the experimental and control groups or the two training groups combined.

(2) In all 3 experiments, learning occurred during device familiarization training and pretesting, and this learning elevated already high ceiling and practice effects.

d. Consideration: A major factor which may have hindered finding any effects of training transfer from TOPGUN to I-COFT could have been the differences in the skill requirements for the two devices; i.e., skills learned during pretesting on I-COFT may have completely masked any general skills training from TOPGUN.

6. Related Work:

a. Cochran, W. G., & Cox, G. M. (1957). Experimental design (2nd ed.). New York: John Wiley & Sons, Inc.

b. General Electric Company (1985). Instructor's utilization handbook for the M1 Unit-Conduct of Fire Trainer (U-COFT). Orlando, FL: Naval Training Equipment Center, US Army Program Manager Training Devices.

c. SPSS, Inc. (1988). SPSS/PC+ V3.0 for the IBM PC/XI/AT and PS/2. Chicago, IL.

d. NKH, Inc. (1986). TOPGUN design specifications. Carlsbad, CA: Author.

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19. Kraemer, R. E., & Wong, D. T. (1992). Evaluation of a prototype Platoon Gunnery Trainer (PGT) for Armor Officer Basic Course (AOBC) training (ARI Research Report 1620). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A254 289)

1. Topic Keywords: Armor; M1 Tank; Training Devices; PGT; Training Effectiveness; Training Capability Assessment; AOBC.

2. Short Summary: A prototype Platoon Gunnery Trainer (PGT) was evaluated to support the draft U.S. Army Armor School (USAARMS) Combined Arms Training Strategy (USAARMS, 1990). Ninety-five Armor Officer Basic Course (AOBC) students were trained in groups of 8 (12 platoons) using 4 alternating iterations of the same offensive and defensive training exercises. The results showed significant improvement (as measured by Table XII type scores) in platoon tactical, gunnery, and summary performance across trials (platoon training order) for both types of exercise (offense and defense), and when the exercises were combined. Linear trend analyses indicated that tank platoon performance improved across trials in approximate proportion to amount of training received. The results thus indicated that the prototype PGT effectively trains platoon gunnery and tactical skills in the institution.

3. Performing organization: U.S. Army Research Institute for the Social and Behavioral Sciences, ARI Field Unit - Fort Knox, Fort Knox, KY 40121-5620.

4. Approach: Experimental

a. Number of Groups: 1

b. Description of Group: The subjects were 95 officers attending AOBC. Their median time in military service was ten months, average M1 tank experience was .50 months, and average training device experience was 36.83 hours, with most of this training time spent on the M1 U-COFT (36.04 hours). None of the students had prior training on the prototype PGT.

c. Tests or Trials: The 95 AOBC students were trained and tested on the prototype PGT in groups of eight (except for one group of seven) as separate tank platoons (N=12). Each student rotated through the different leadership positions within the platoon during an eight hour training session. At the end of each platoon offensive or defensive training exercise, a Battle Run Summary printout was used to critique each platoon's gunnery performance. Also, a platoon summary scoresheet was completed by a single investigator to measure platoon tactical performance.

d. Number of Different Types of Measures Used: 3

e. Description of Measures/Ratings: A total of 14 platoon tactical measures of performance (MOPs) were identified, listed on an observational platoon summary scoresheet, and evaluated using a 5-point rating scale. A tactical points score (T-PTS) was derived by summing the rating points awarded for each type of training exercise. The tactical points score was converted to a Table XII type platoon tactical score (TSUM) by dividing the total points awarded by the total possible during an exercise (52 for offense and 48 for defense) and multiplying by 200. A platoon gunnery points score (G-PTS) was derived by dividing the

total number of targets killed by the total number of targets presented (46 for offense, 41 for defense), as shown on the Battle Run Summary printout provided by the prototype PGT. A Table XII type platoon gunnery score (GSUM) was derived by multiplying the G-PTS score by 300. A Table XII type platoon summary points score (XIISUM) was derived by summing the TSUM and GSUM scores. A biographical questionnaire was administered at the end of each training session.

f. Experimental Setting/Training Context: All training and testing was conducted in an institutional training setting by a mix of five military and civilian Instructor/Operators (I/Os). A total of 12 hours of PGT training are incorporated into a USAARMS program of instruction (POI) for AOBC; four hours of classroom instruction in platoon tactics using a sandtable model of the PGT data base, followed a week later by eight hours of device-based training. The instructional strategy can be described as a team approach wherein students are provided instruction and training feedback by the designated CO and the I/Os located at each M1 U-COFT. At the end of one or more exercises, after-action reviews (AARs) are conducted by the CO based on his notes and gunnery data provided on the Battle Run Summary printout.

g. Statistical Methods: The data were analyzed using the procedures contained in the Statistical Package for the Social Sciences (SPSS/PC+, 1988). In data analyses, the test statistics were judged statistically significant with alpha equals .05. The data were analyzed across trials (platoon training order) for each type of training exercise (offensive or defensive) and when combined. The objectives were to determine: (1) if AOBC student performance improved on each of the 14 MOPs and the three criterion measures (TSUM, GSUM, XIISUM) and (2) whether such performance improved across platoon training order. The test statistics used for data analyses were t-test (based on Fisher's z-transformation of Pearson's correlations) and a trend analysis conducted within a multivariate analysis of variance (MANOVA). Individual Pearson correlation coefficients were not tested due to non-independent groups for each platoon training order. Basic descriptive statistics were used to summarize biographical data.

h. Stage of Training: AOBC

i. Trainee Sophistication: Intermediate

5. Discussion:

a. Major Findings:

(1) Platoon-level skills which could be trained on the PGT were identified from the Army Training and Evaluation Program (ARTEP), Mission Training Plan (MTP) for the Tank Platoon (ARTEP 17-23710-MTP, Department of the Army, 1988a).

(2) Measures of performance (MOPs) which could be used to quantify changes in platoon tactical skill proficiency were

developed with subject matter experts and incorporated measures identified by Drucker and Campsure (1990), the Exercise/After-Action Review (AAR) Checklist used by the PGT training staff, and the Tactical Proficiency Checklists used for Tables XI/XII (FM 17-12-1, C3, Department of the Army, 1988b).

(3) Pilot test results revealed a significant average interrater reliability between CO and ARI raters ($\underline{r}$ = .86), all but 3 MOPs correlated significantly between raters, and criterion measures for platoon performance showed a positive relationship to training order.

(4) Formal testing revealed that the TSUM and XIISUM scores correlated highly with platoon training order for offense, defense, and combined exercises while the GSUM score correlated moderately.

(5) Trend analysis revealed a significant platoon training order effect for all three criterion measures, criterion performance steadily improved across platoon order in approximate proportion to the added training received, and performance gains differed from platoon to platoon due to variations in training methods and prior experience.

b. Authors' Conclusions:

(1) The prototype PGT being used by the USAARMS was highly successful in improving the platoon tactical and gunnery skill proficiency of AOBC students.

(2) The platoon tactical and gunnery performance of AOBC students improved significantly by platoon training order in approximate proportion to the additional training received.

(3) The platoon summary scoresheet and scoring methods can be used to collect and assess platoon tactical and gunnery performance on the prototype PGT.

c. Limitations:

(1) The platoon tactical performance data were based on ratings obtained by a single investigator using a platoon summary scoresheet. As such, rater bias was possible which could have affected the results.

(2) The order in which the AOB students trained on the device was not random; students within each group determined the platoon training order. Had one or more of the crews within a platoon showed a distinct lack of proficiency in either tactical or gunnery performance, a rearrangement in the order or a revised sequencing of exercises presented during training could have produced different results.

(3) Several different trainers were used at the CO and I/O positions, not all trainers demonstrated the same training

abilities or followed the standardized syllabus developed for PGT training, and there was a tendency to complete training on the PGT in one 8-hr block rather than two separated 4-hr periods.

d. Considerations: Noncomparative measurement is usually considered the simplest form of quantitative assessment that can be used to evaluate training device effectiveness. Moreover, the performance measured on the prototype PGT was not compared with alternate training methods, training on any other devices, or with performance in an operational or field setting.

6. Related Work:

a. Department of the Army (1988a). Tank combat tables (Field Manual 17-12-1, C3). Washington, DC: Author.

b. Department of the Army (1988b). Mission training plan for the tank platoon (ARTEP 17-237-10-MTP). Washington, DC: Author.

c. Drucker, E. H., & Campshure, D. A. (1990). An analysis of tank platoon operations and their simulation on Simulation Networking (SIMNET) (ARI Research Product 90-22). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A226 956)

d. General Electric Company (1990). Instructor's utilization handbook for the M1 Unit Trainer (UT-12) (GE Document No. 48B-%%%-%%%). Daytona Beach, FL: Author.

e. SPSS, Inc. (1988). SPSS/PC+ V3.0 for the IBM PC/XI/AT and PS/2. Chicago IL: Author.

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20. Kress, G. (HumRRO) (1981). Validation of tank gunnery training tasks (ARI Technical Report 521). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A119 053)

1. Topic Keywords: Armor; M60A3 Tank Gunnery; Training Devices; M55 Laser; Cal .22; Subcaliber Devices; Full Scale; 1/60 Scale; 1/20 Scale; Crew Turbulence; Measurement: Tank Table VIII.

2. Short Summary: This research examined the (a) relationship between performance on M60A3 critical crew training tasks and Tank Table (TT) VIII performance, and (b) relationship between crew members' job experience and attitude measures and TT VIII performance. Tank commanders (TCs) and gunners from 54 crews were tested on nine tasks ranging from basic skills (ability to select the correct sight picture for initial lay) to more complex tasks (simulated engagements using subcaliber fire and scaled ranges). Also collected were data on crew turbulence and TC and gunner job experience. Organizational Climate and Leadership

questionnaires were administered to all crew members. Following their annual live-fire TT VIII, speed and accuracy measures were collected and correlated with each of the training task measures, turbulence and experience measures, and attitudinal measures. The results revealed that (a) performance on the subcaliber range (1/60 scale cal. 22) was the best predictor of TT VIII, (b) there was no positive relationship between crew turbulence measures and tank gunnery performance, and (c) the gunner's job experience was positively correlated with TT VIII performance.

3. Performing Organization: Human Resources Research Organization (HumRRO), 5001 Eisenhower Avenue, Alexandria, VA: 22314.

4. Approach: (Analytical)

a. Number of Groups: 1

b. Description of Groups: The group consisted of tank crew members from one U.S. Army Europe (USAREUR) M60A3 battalion (54 crews). The main focus was on the 54 pairs of TCs and gunners, but attitudinal data were collected on all 216 crew members.

c. Tests or Trials:

(1) Predictor Variables: Three types of predictor variables were used: (1) training program predictors consisting of measures of critical skills and knowledge identified in the Integrated Tank Gunnery Training Program Outline developed for USAREUR units (Sharon, Kress, & McGuire, 1980); (2) attitudinal predictors based on measures of organizational climate and perceived leadership; and (3) background characteristics which included measures relating to length of job experience and crew turbulence. The training program predictors fell into three categories: knowledge (paper-and-pencil tests), motor skills, and simulated engagements. The attitudinal predictors consisted of the Leadership Behavior Description Questionnaire 12 (LBDQ) and a General Organizational Questionnaire (GOQ). The LBDQ is given to subordinates who describe their supervisors' behavior in terms of two dimensions called "Consideration" and "Initiating Structure". The GOQ, which has been used by the Army since the mid-1970's to assess organizational climate, contained four major scales--Unit Climate, Supervisory Leadership, Group Cohesion, and Mission Accomplishment. The final variable consisted of measures of tank crew stability and crew member job experience, adapted from a similar questionnaire developed by Eaton and Neff (1978).

(2) Performance Variables: The performance variable was measures of TT VIII performance. A moving main gun engagement (two rounds) was added to TT VIII to increase the number of such engagements, and the TCs were instructed to fire both rounds at the target even if they scored a hit with the first round. TT VI and VII measures, day engagements only, were used to evaluate the reliability of scores among the three tables. All measures were based on main gun hit-miss scores and elapsed time.

d. Number of Different Types of Measures Used: Nine training program predictors, two attitudinal predictors, several personnel background predictors, and six TT VI (Day), VII (Day), and VIII (day and night) criterion performance variables

e. Description of Measures/Ratings:

(1) Training Program Predictor Measures: Three tasks were tested using knowledge (paper-and-pencil) tests. Two tested the gunner's knowledge of how to take a correct initial sight picture for a first round hit and how to lay the sight reticle correctly during fire adjustment for a second round hit. The third task tested the TC's ability to determine the correct fire adjustment following a first round miss. For all three tests, the dependent measure was the percentage correct responses. Three perceptual-motor skills were tested using an M55 laser mounted on a Brewster device. The first two tested the gunner's ability to hit 40 stationary and moving targets using the primary sight. The response measure were percent targets hit and the mean time per trial. The third tested the TC's ability to determine the range to seven full scale panel targets, using unaided and aided (the coincidence rangefinder) techniques. The dependent measures were the mean ranging error for both range determinations. Simulated TC/gunner tasks were tested using full scale plus M55 laser, 1/20 scale plus M55 laser, and 1/60 scale plus cal. 22. For the scaled engagements, the target arrays, simulated distances, and types of engagements were identical. A total of seven engagements within battlesight ranges (800-1300 meters) including 14 targets were fired on each range using the primary sight. Two shots per target were allowed for all seven engagements. The order was counterbalanced across crews to control for learning effects. The performance measures were the total percentage hits, percentage first round hits, mean opening time, and mean total time per engagement. For the full scale laser engagements, frontal tank target panels were placed at actual distances from 700 to 1900 meters. A total of 11 target engagements involving 17 targets were randomly presented with simulated battlesight and precision engagements, single and multiple targets, and HEAT and APDS ammunition. Two shots were allowed per target. Total percent hits, percent first round hits, mean opening time, and mean total time were the dependent measures.

(2) Criterion Performance Variables: The primary test of tank crew gunnery proficiency is Tank Table VIII. Prior to firing TT VIII, all crews fired TT VI (Day) involved two moving tank targets and 10 stationary targets. Table VII (Day) involved one moving tank and seven stationary targets. TT VIII included both day and night engagements for a total of four moving targets and 10 stationary targets. Data recorded on the battalion's scoresheets for each tank gunnery table was used to compute six measures of gunnery performance: (1) percent hits (number of targets hit divided by number of rounds fired times 100), (2) percent first round hits (number of targets hit by the first round divided by number of targets engaged times 100), (3)

percent targets hit (total number of targets hit divided by number of targets engaged times 100), (4) percent successful engagements (number of engagements in which all targets were hit divided by number of engagements completed), (5) mean opening time (sum, across engagements, of elapsed time from target appearance to first round divided by number of engagements), and (6) mean total time (sum, across engagements, of elapsed time from target appearance to last round divided by number of target engagements).

f. Experimental Setting/Training Context: The data were collected from tank crews trained and tested in a live-fire field setting on TT VI, VII, and VIII. In Phase I, data relating to the predictor variables were collected at home station in the week prior to the battalion moving to the Grafenwoehr training area. Paper-and-pencil tests and data questionnaires were administered on a group basis. Tests on motor skills and simulated engagements were set up as individual stations and gunner or TC-gunner pairs rotated through the stations. One company per day was tested and an additional day was used for make-up tests. In Phase II, the criterion performance data were collected at Grafenwoehr during the battalion's scheduled gunnery period. All crews fired TT VI, VII, and VIII in that order. The data were collected using specially prepared score sheets for each table and standardized scoring procedures. One team scored all of TT VI, another scored all of TT VIII, and the scoring of TT VII was divided between the two teams. Scoring was performed using 7 x 50 binoculars. On TT VI scorers were positioned in the control tower with two people dividing the targets and sensing and one person recording the results. On TT VII and VIII, one scorer and one data recorder rode in the control jeep which followed the firing tank. On TT VIII moving targets were sensed and then physically scored for hits after the firing tank passed the position. Time data were recorded for all tank tables using stop watches. For each engagement on TT VIII, two stop watches were started simultaneously when a target first appeared. The first watch was stopped at the sound of the first round (opening time) and the second watch was stopped either when all the targets had been hit or time was called by the controller (total time).

g. Statistical Methods: Pearson correlation coefficients were used to examine the relationships between (1) training variables, (2) experience variables, (3) attitudinal variables and criterion gunnery performance (TT VIII). To determine the relative contributions of all three variables in predicting TT VIII performance, a set of multiple regression analyses were conducted to include selected measures from the three sets of variables. A step-wise multiple regression analysis was computed for each TT VIII deperdent variable using the best set of predictor variables for each analysis. For the overall analysis, it was assumed that missing data occurred randomly with respect to their effect on the variables being measured. In all data analytic procedures the maximum number of cases appropriate for each variable was computed. This often resulted in an unequal

number of subjects across variables and data analytic procedures. When multiple regression analyses were calculated, all cases were dropped which did not have complete data for all variables. This resulted in an equal number of cases for all variables in the regression; however, the total number of cases was also reduced.

h. Stage of Training: Annual gunnery training density

i. Trainee Sophistication: Tank crew members with a wide range of gunnery experience levels.

5. Discussion:

a. Major Findings:

(1) None of the correlation coefficients calculated between corresponding performance measures across the three gunnery tables were found to differ significantly from zero. That is, performance on TT VI and VII did not predict TT VIII performance, nor were the measures related across the tables.

(2) The ability of the gunners to track and hit moving targets using the M55 laser related positively and significantly to the accuracy scores achieved on TT VIII.

(3) Accuracy in hitting stationary targets with the M55 laser was correlated positively and significantly with mean total time on TT VIII engagements; i.e., increased accuracy with the M55 laser was related to longer TT VIII engagement times. There also was a significant positive relationship between mean time per trial on this training task and mean TT VIII opening time.

(4) No relationships were found between (a) TC training tasks (ranging and knowledge of fire adjustment methods) and (b) gunners' knowledge of initial lay and fire adjustment procedures, and TT VIII gunnery performance.

(5) Performance by type of engagement condition on the three knowledge (paper-and-pencil) tasks showed that both TC and gunner were most proficient on the types of skills required on TT VIII and considerably less proficient on those not required.

(6) Speed and accuracy of performance on the 1/60 scale cal .22 engagement method was significantly related to a number of corresponding measures on TT VIII. All relationships were in the right direction; i.e., better performance on the simulation method was related to better performance on the gunnery table.

(7) The Full Scale and 1/20 Scale M55 laser engagement methods also showed some significant relationships to TT VIII; however, they were not as numerous or as consistent as the 1/60 Scale cal .22 engagement method.

(8) Cal .22 opening time and percent first round hits were the best predictors of TT VIII accuracy measures while cal

.22 opening time and total time were the best predictors of TT VIII speed measures.

(9) Crew turbulence in the armor battalion was high. During about a two-month period, 50% of the tank duty positions were filled by different crew members and 38% were filled by new crew members who had just joined the crew.

(10) There was no relationship between either how long a crew or the TC and gunner had been assigned together and how well the crew performed on TT VIII; i.e., crew turbulence was not directly related to gunnery performance.

(11) None of the TC experience measures were related significantly to any of the TT VIII measures. The amount of experience the gunner had in the company, in M60A3 tanks, and number of gunnery tables fired, all related significantly to TT VIII accuracy measures. The time the TC and gunner had served together was unrelated to performance.

(12) The TC's perception of Group Cohesion related positively to accuracy on TT VIII. Also, the TCs' perception of the degree of consideration shown by his leader was negatively related to gunnery performance. No significant relationships were found between gunner attitudes and TT VIII performance.

b. Authors' Conclusions:

(1) Home station training on subcaliber mini-tank ranges (Full Scale + M55 Laser, 1/20 Scale + M55 Laser, 1/60 Scale + cal .22) was positively related to TT VIII gunnery proficiency.

(2) Performance on the subcaliber mini-tank range (1/60 Scale cal .22) was the best predictor of TT VIII performance.

(3) There was no relationship between crew turbulence measures and TT VIII gunnery performance.

(4) The gunner's job experience was positively related to TT VIII gunnery performance.

c. Limitations:

(1) The relatively small sample of tank crews that was involved in the data analysis, all from one battalion, may not meet the statistical requirements for external validity and generalizability of results.

(2) The percent hits and percent first round hits for the Full Scale and 1/20 Scale laser engagements were close to perfect performance (100%). Performance on the two methods may have produced a "ceiling effect" which (a) limits the possibility of discriminating between better and poorer performers and (b) reduces the size of the correlation coefficient among methods, and between the methods and TT VIII. Also, the three methods

were not equivalent in difficulty level, and these differences probably contributed substantially to the lower accuracy scores on the 1/60 Scale cal .22 method.

d. Considerations: The TT VIII performance measures may be compromised if the data are not based on each tank crew's first run scores. As described in the latest FM 17-12-1, the battalion commander has the discretionary authority to have a crew refire any or all engagement tasks which it failed during its first run. Moreover, it's not known whether the 81% TT VIII qualification rate of the battalion is representative of the population of USAREUR armor units. For example, Hoffman (1989) reported that 95.5% of M1 crews passed Table VIII at Grafenwoehr.

6. Related Work:

a. Department of the Army (1988). Tank combat tables M1 (Field Manual 17-12-1). Washington, DC: Author.

b. Eaton, N. K., & Neff, J. R. (1978). The effects of tank crew turbulence on tank gunnery performance (ARI Technical Paper 350). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A061 178)

c. Hoffman, R. G. (1989). Description and prediction of Grafenwoehr M1 tank table VIII performance (ARI Technical Report 837). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD B136 331)

d. Sharon, B., Kress, G., & McGuire, W. J. (1980). Integrated tank gunnery training program outline for USAREUR units (HumRRO Final Report). Alexandria, VA: Human Resources Research Organization.

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21. Kuma, D., & McConville, L. (1982). Independent evaluation report for M1/M60 series Unit Conduct of Fire Trainer (UCOFT) (TRADOC ACN 39373). Fort Knox, KY: U.S. Army Armor Center, Directorate of Training Developments. (AD B065 441)

1. Topic Keywords: M1 Tank; M60 Tank; Tank Gunnery Training; Training Devices; UCOFT; Performance Evaluation; Training Effectiveness; Training Transfer Effectiveness

2. Short Summary: This Independent Evaluation Report (IER) on the Unit-Conduct of Fire Trainer (U-COFT) for the M1 and M60 Series tanks was designed to provide the U.S. Army Training and Doctrine Command (TRADOC) the basis on which a decision to enter production could be formulated. The data used in this evaluation were derived from the M1/M60 U-COFT Developmental Test, M1 U-COFT Operational Test, M1 U-COFT Maintainability Demonstration, and the M60A1 Breadboard Demonstration. The results of the IER

revealed that (a) the essential training device requirements (TDR) for training transfer effectiveness, safety, and instructor operability were met and (b) the essential TDR for Reliability, Availability, and Maintainability (RAM) and logistical support were not met. The IER noted that reliability and maintainability should improve to TDR levels as the system matures, logistical supportability could not be tested since the Built-in-Test Equipment (BITE) did not work, and that additional testing will be required to ensure the U-COFT support concept is viable.

3. Performing Organization: U.S. Army Armor Center, Directorate of Training Development, Fort Knox, KY 40121

4. Approach: Analytical

5. Discussion:

a. Major Findings:

(1) Testing was adequate (for critical operational issues) to support a decision on all issues for both the M1 and M60 series U-COFTs except for logistical supportability which could not be addressed since the BITE did not function.

(2) The U-COFT training program provides a satisfactory level of training effectiveness.

(3) The U-COFT is safe in an operational environment.

(4) Logistical supportability issues could not be addressed based on testing since the BITE did not function; however, it appears that the I/O can operate BITE and minimal risk is associated with the issue since the contractor supports all levels of maintenance above operator.

(5) In the area of RAM, the U-COFT met the availability requirement which is the most critical one for a training device. The U-COFT did meet the maintainability requirement during such demonstration following the Operational Test (OT). Following a fix and test phase, minimal risk was related with the reliability requirement issue.

(6) The subjective evaluation of the M60A1 breadboard U-COFT indicated the components evaluated were a true simulation of the M60A1 tank with the exception of the rangefinder which had a shortcoming in its functioning. No operational test for the M60 series tank U-COFTs is required.

b. Authors' Conclusions: The TRADOC Combined Arms Testing Activity (TACATA) Operational Test (OT) II test report and TRADOC System Analysis Activity (TRASANA) Training Development Study (TDS) support the conclusion that the U-COFT is an effective training device provided the problem areas identified are fixed. The U-COFT will allow tank crews to train throughout the year partially alleviating inability of tank crews to sustain their

proficiency due to shortages of ammunition, fuel, and range facilities. In addition, the U-COFT will provide a medium through which units can train newly arrived personnel and cross train crewmembers regularly.

c. Limitations:

(1) Small numbers of available M1 crews for testing may have affected the ability to detect and attribute differences to crew proficiency.

(2) Crews were not grouped according to performance scores, but maintained company integrity throughout testing. This may have biased the results because unit influences may have been stronger than training program influences.

(3) The test duration may not have been long enough to fully address sustainment training and RAM. Transition training was not test[illegible] objectively by TACATA; however, some objective data was ob[illegible]d by the TDS team.

(4) The baseline sustainment training program included all crewmembers while the U-COFT training program provided training for only the TC's and gunners.

(5) The baseline group was excluded from portions of the Annual General Inspection (AGI) while the U-COFT companies were required to meet all AGI requirements.

(6) Data on two critical performance measures (reticle lay error and range error) were not collected during the initial battlefield firing diagnostic (BFD) test. This was considered a major shortcoming since U-COFT crews were progressed through their training program based on lay error.

(7) Range conditions on the final BFD test were not consistent. For example, dust caused by firing and tank movement cleared quickly during the baseline group's test, but took longer to disperse on the following days when the U-COFT group fired.

(8) U-COFT tank crew attitudes may have been negatively influenced because they were required to attend U-COFT training when the rest of the unit was off duty. Because they received no compensatory time, the crews felt they were unfairly treated during the test and it often resulted in poor training sessions.

(9) The commander of the baseline company was physically present for virtually all training program, while the commanders of the U-COFT companies were not. Thus, comparisons between the two alternative training programs are invalid.

(10) The baseline group was able to evaluate the final test requirements (i.e., acquired and fired on the moving target first even though this technique runs contrary to doctrine). Also, the target was always exposed due to range limitations.

6. Related Work:

a. Butler, W. G., Reynolds, M. J., Kroh, M. Z., & Thorne, H. W. (1982). Training development study--M1 (Abrams) Tank Unit-Conduct of Fire Trainer (TRASANA TEA 11-82). White Sands Missile Range, NM: U.S. Army TRADOC System Analysis Activity. (AD B954 521L)

b. U.S. Army Test and Evaluation Command (TECOM). Test Report, Developmental Test II of the M1, M60 and M2/M3 Unit-Conduct of Fire Trainer (U-COFT): Volume I (M1 U-COFT Test Phase), Jan 82, and Volume 3 (M60 U-COFT Phase), Apr 82. Ft Hood, TX: Author.

c. U.S. Army Training and Doctrine Command (TRADOC) Combined Arms Test Activity (1982). M1 Unit-Conduct of Fire Trainer (U-COFT) (TCATA Test Report, CTN 547). Fort Hood, TX: Author.

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22. Lampton, D. R., Bliss, J. P., & Meert, M. (1992). The effects of differences between practice and test criteria on transfer and retention of a simulated tank gunnery task (ARI Technical Report 949). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A251 867)

1. Topic Keywords: Armor; Training Devices; VIGS Training Strategies; Instructional Strategies; Gunnery Training: Skill Retention; Transfer of Training.

2. Short Summary: This research evaluated manipulation of the difficulty of practice criteria, relative to test criteria, as a method of improving gunnery performance on track-and-shoot tasks. The experimental task required manual tracking and firing using a Videodisk Gunnery Simulator (VIGS). Forty-five students were randomly assigned to one of three groups who practiced under an accuracy criterion which was (a) easier than, (b) more difficult than, or (c) same as the transfer and retention test criterion. The accuracy criterion was defined as the percentage of target area scored as a kill when hit; i.e., kill zone (KZ). The three criterion measures were target kills, aiming error, and time-to-fire. The results revealed that VIGS practice with an accuracy criterion more difficult than the test criterion yielded greater hit percentages but slower firing times: a speed/accuracy tradeoff. This trend, though not statistically significant, held for both transfer and retention test scores. Also, practice with an easier accuracy criterion did not result in any systematic differences from control group performance.

3. Performing Organization: U.S. Army Research Institute for the Behavioral and Social Sciences, PM TRADE Field Unit, 12350 Research Parkway, Orlando, FL 32826-3276; University of Central Florida (UCF), Institute for Simulation and Training (IST), P.O. Box 25000, Orlando, FL 32816.

4. Approach: Experimental

a. Number of Groups: 3

b. Description of Groups: The subjects were 45 male undergraduate students attending the UCF who were paid for their participation. Each subject avowed normal color vision, signed a consent form, completed a background questionnaire (reporting their age, grade level, and amount of video-game experience). and received about two hours of VIGS training and testing.

c. Tests or Trials:

(1) Subjects in KZ150% Group: The 15 subjects received VIGS orientation followed by three blocks of practice engagements (trials), each containing 18 trials per block with the kill zone set at 150% of the target silhouette. Each subject received three of five randomly chosen sequences. The five sequences were created from nine scenarios contained on VIGS disk #1, with each scenario appearing twice per block in random order (except that the same scenario could not appear consecutively). Following training, the subjects were tested with a 100% KZ using 20 similar, but not duplicate engagements from either VIGS disk #2 or #3. The odd numbered subjects were tested with exercises from VIGS disk #2, while even numbered subjects were tested with exercises from VIGS disk #3. Five subjects returned 10 weeks later for a retention test consisting of 18 engagements from VIGS disk #1 and 20 test targets from the same disk they had received during the transfer test. Both blocks of retention trials were given on one day, with a five-minute break between blocks.

(2) Subjects in KZ50% Group: Same as above, except the 15 subjects practiced engagements with the KZ set at 50% of the target silhouette and five returned for the retention test.

(3) Subjects in KZ100% (Control) Group: Same as above, except the 15 subjects practiced engagements with the KZ set at 100% of the silhouette and four returned for the retention test.

d. Number of Different Types of Measures Used: 3

e. Description of Measures/Ratings: The speed measure was time-to-fire (in seconds), which began when automatic slewing of the main gun stopped and ended when the student pressed the firing button. The accuracy measures were aiming error and kill percentage. The aiming error score was calculated as the point-of-impact; a round's vertical and horizontal displacement in milliradians from the center of target mass at the time of the round's impact. Kill percentage was the number of kills divided by the number of rounds fired in each training and test block.

f. Experimental Setting/Training Context: The research was conducted in an institutional setting using standardized sets of instruction for both hands-on training and testing. Each subject (one at a time) was given 15-minutes of VIGS orientation (which

described the experimental task, the VIGS controls, the target scenarios, and target KZ setting) followed by five-minutes of practice using the VIGS. The experimental task required each subject to: (1) flip a switch to index the type of ammunition specified for the scenario, (2) manipulate the manual controls to place the aiming cross within the target silhouette, (3) press a button to "lase" the target, (4) track the target for at least one and one-half seconds, and (5) press another button to fire the round at the target. After firing, (only one round per target), the subject was directed to observe the impact of the round and then look away from the VIGS sight until the beginning of the next scenario. A five-minute break was given after each block of practice. For the fourth block (test), the experimenter described the change, if any, in the size of the KZ. After test completion, the subjects were paid and asked to return for a 10-week retention test. For the retention test, each subject was tested with the original set (and added block) of scenarios from VIGS disk #1 (Form 1), given a five-minute break, and tested with a second block of VIGS disk #2 or disk #3 scenarios (Form 2).

g. Statistical Methods: Data analyses were conducted using the Statistical Package for the Social Sciences (SPSS). Group means and standard deviations were calculated for each dependent measure for each block of trials. Mean time-to-fire, aiming error, and target kills were analyzed as functions of block of practice, transfer, and retention trials for each KZ percentage. To examine practice effects, a doubly multivariate analysis of variance (MANOVA) was conducted on performance (trial blocks 1-3), with a between-subjects factor of group assignment, a within-subjects factor of trial block, and the three dependent measures. Univariate ANOVAs were calculated for each of the three dependent variables, as necessary to examine significant main effects for practice performance. Duncan multiple range tests were conducted for each dependent measure to determine differences among groups. Separate MANOVAs were conducted on the transfer test and the two blocks of the retention test. Separate ANOVAs were conducted for each dependent measure for the test block, retention block 1, and retention block 2. Difference scores were calculated as was a Cronback alpha measure of test reliability for each test used for the transfer test. Excluded from the analyses were engagements in which subjects made a procedural error, such as indexing the wrong ammunition. Such errors prevented the determination of the subjects's aiming point at the time of firing; the point of round impact does not correspond to the aiming point.

h. Trainee Sophistication: Novice

i. Use of Instructional Features: During the research, a shield was placed at the side of the M1 VIGS Cathode Ray Tube so that subjects could not view, or be distracted by, the gunnery performance information displayed on the screen. Also, the VIGS was modified to include a printer to create hardcopy printouts of performance reports (information dumps from the data screens) and a keyboard to initiate printouts and alter some VIGS parameters.

5. Discussion:

a. Major Findings

(1) For each block of practice trials, KZ150% had the highest kill percentage followed by KZ 100% and KZ 50%. This pattern, as expected, corresponded to the differential criteria, determined by kill zone setting, used during the practice blocks.

(2) KZ50% had the slowest time-to-fire across all practice blocks, with KZ100% and KZ150% having similar means across all blocks. KZ50% also displayed a consistent superiority (smallest mean aiming error) across all blocks.

(3) For the practice data, significant main effects were found for group assignment and trial block, indicating that gunnery performance differed as a function of group assignment and as a function of amount of practice. The interaction of group assignment and block was not significant.

(4) Univariate ANOVAs for each of the three dependent measures paralleled the doubly MANOVA results; group and trial effects were significant with no significant interactions.

(5) Duncan multiple range tests conducted for each dependent measure indicated that the means for KZ50% differed significantly from the means for KZ100% and KZ150%, which did not differ significantly. All ANOVAs were significant.

(6) Separate MANOVAs conducted on the transfer test and two blocks of the retention test were not significant. ANOVAs conducted for each of the three dependent variables for the test block and retention blocks were also not significant.

(7) The Cronback's alpha measure of test reliability for VIGS disk #2 and #3 scenarios was .53 and .56, respectively.

b. Authors' Conclusions: The two hypotheses were not supported. Practice with a more difficult accuracy criterion (KZ50%) or with an easier criterion (KZ150%) did not lead to significantly better transfer or retention scores when the criterion (KZ100%) was relaxed.

c. Limitations:

(1) The manner in which VIGS was used for research was inappropriate because scenarios varied greatly in their levels of difficulty; i.e., did not allow for identification, measurement, or control of the dimensions of scenario difficulty.

(2) Extremely low kill rates were obtained with some VIGS scenarios. For the worst two cases, less than 5% of the rounds fired were kills. This may be indicative of technical problems with the VIGS in coding target location to determine if a shot is a hit or miss.

(3) The instructions only covered the basics of gunnery. They did not cover more complex aspects of tank gunnery such as handling multiple range returns or target tracking procedures for engagements in which movement is not limited to a horizontal plane.

(4) Limiting subjects to firing only one round per target engagement avoids across subject variation in the number of rounds fired during acquisition and testing. It also differs from standard use of gunnery simulators and live-fire conditions for which multiple firing is allowed and sometimes required.

(5) Though less than one-third of the subjects returned for retention testing, little or no performance loss was shown on Form 1 of the retention test; thus, a poor choice was made in selecting tasks to exam practice effects variables on retention.

d. Considerations: The speed/accuracy tradeoff differs from results reported by Abel (1986) which indicated an emphasis on speed over accuracy for a similar task with a reduced kill zone setting. Limiting subjects to one round per engagement may have possibly resulted in an emphasis on firing accuracy.

6. Related Work:

a. Abel, M. H. (1986). Performance of soldiers on the Battlesight Gunnery Video Game (ARI Technical Report 710). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A178 446)

b. ECC International Corp (1988). M1/M1A1, Tank Videodisk Gunnery Simulator (VIGS), Device 17-142: Instructor's utilization handbook for simulation equipment. Orlando, FL: Author.

c. Turnage, J. J., & Bliss, J. P. (1989). An analysis of skill transfer for tank gunnery performance using TOPGUN, VIGS, and ICOFT trainers (ARI Technical Report 916). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A231 156)

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

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23. Landers, M. D., & Hunt, K. T. (1991). Guard Unit Armory Device Full-Crew Interactive Simulation Trainer for Armor (GUARD FIST I) customer test. (Final Report 91-CT-990). Fort Knox, KY: U.S. Army Armor and Engineer Board. (AD B154 266)

1. Topic Keywords: Armor; ARNG; M1 Tank; Tank Gunnery Trainer; Training Device; GUARDFIST I; Phoenix/Wallentine Inbore Device; M1 Tank Gunnery Training; Full Crew Trainer.

2. Short Summary: This customer test evaluated the operational and gunnery performance of a Guard Unit Armory Device, Full-Crew Interactive Simulation Trainer for Armor (GUARDFIST I). Tank crews from two M1 Army National Guard (ARNG) Armor battalions were randomly selected by platoon and divided into two separate groups. Crews in the experimental group (GUARDFIST) received one one-hour device training session for each monthly unit training activity (MUTA) over a period of six months, in addition to the normal weekend training. Crews in the control group conducted normal weekend training only. Following training, crews from one battalion (both groups) fired a modified Tank Table (TT) VII (except for one company) and TT VIII during annual gunnery training using main gun practice ammunition. Crews from the other battalion (both groups) fired a subcaliber, modified TT VIII using the Phoenix/Wallentine inbore device. Results of the GUARDFIST I operational test revealed that the device: (a) did not impede normal M1 tank operation, (b) did not support tank crew procedures training, (c) the training program did not prepare I/Os to use and maintain GUARDFIST I in an operational environment (fixed facility), (d) did not meet the reliability, availability, and maintainability (RAM) requirements in a training environment, (e) logistical support concept did not support operational requirements, and (f) was not designed according to human factors engineering (HFE) principles, and (g) contained safety and health hazards. Results of the GUARDFIST I gunnery test revealed that: (a) GUARDFIST crews had higher mean net-point score estimates than control group crews (i/e., demonstrating positive training transfer), and (b) GUARDFIST crews had higher mean crew cuts scores than control group crews (i.e., demonstrating a deterioration in tank crew cohesion).

3. Performing Organization: U.S. Army Test and Experimentation Command (TEXCOM), Armor and Engineer Board (AEBD), Fort Knox, KY 40121-5470.

4. Approach: Customer Test

a. Number of Groups: 2

b. Description of Groups:

(1) Subjects in GUARDFIST Group: The subjects were 48 ARNG tank crews; 28 from a South Carolina battalion (Group 1) and 20 from a North Carolina battalion (Group 3). The tank crews received one one-hour session of GUARDFIST I training for each MUTA over a period of six months, in addition to normal training. A seventh session was added for Group 3 at the end of the test (excursion) to evaluate the tank commander's (TC's) remote keypad for selecting exercises and controlling training sessions. After training, crews from one battalion (both groups) fired a modified TT VII (except for one company) and TT VIII during annual gunnery

training using target practice-tracer (TP-T) and target practice discarding sabot (TPDS) ammunition. Tank crews from the other battalion (both groups) fired a subcaliber, modified TT VIII using the Phoenix/Wallentine inbore device. All tank crewmen completed questionnaires on accuracy of crew functions on the device as compared to those performed on an M1 tank. Crewmen occupying more than one position answered question on all crew positions they occupied during training.

(2) Subjects in Control Group: The subjects were 48 ARNG tank crews; 28 from a South Carolina battalion (Group 2) and 20 from a North Carolina battalion (Group 4). Crews conducted normal weekend training only.

(3) Both Groups: Tank crews in each test battalion were randomly selected by platoon. Crewmen were to remain stable and not switch positions or crews throughout training. The fifth and sixth sessions were conducted during the fifth MUTA. The North Carolina battalion completed their drills at separate armories, whereas the South Carolina battalion merged their four devices at the Leesburg Training Site at Fort Jackson. Demographic data, to include physical characteristics and a summary of military experience, were collected on all participants.

c. Tests or Trials:

(1) Subjects in GUARDFIST Group: The South Carolina battalion fired a modified TT VII and VIII (seven engagements), except for Company C, which fired only TT VIII. These tables were fired using main gun (TP-T and TPDS) ammunition on ranges at Fort Stewart, Georgia. The North Carolina battalion fired a modified TT VIII (seven engagements) using a subcaliber .50 inbore device (Phoenix/Wallentine) on ranges at Fort Bragg.

(2) Subjects in Control Group: Same.

(3) Both Groups: The North Carolina battalion scheduled one company per firing weekend. All crews in each company fired during their respective firing weekends on one range using one scenario. Subcaliber inbore devices were mounted, boresighted, and zeroed on four tanks per gunnery weekend. Tank crews (both groups) rotated on the same four tanks.

d. Number of Different Types of Measures Used: 1

e. Description of Measures/Ratings: TT VIII gunnery scores were recorded for each tank crew. In addition, video and/or audio tapes of all firing were obtained. From these data, three mean scores were used for comparisons: (1) mean engagement points, defined as points accumulated per crew based on point calculation sheets in FM 17-12-1; (2) mean crew cuts, defined as cuts counted against the score per crew; and (3) mean net points, defined as the net score per crew after subtracting scored crew cuts from engagement points. All scenarios (except one) met the guidelines of FM 17-12-1, Tank Combat Tables M1.

f. Experimental Setting/Training Context: All tank gunnery training was established by each test battalion's training programs and conducted at multiple sites using classroom and hands-on training methods. Instructor/Operators (I/Os) for each GUARDFIST group, selected from within each respective unit, were provided instructor and key personnel training (IKPT) from the Armor School, Fort Knox, Kentucky. The IKPT was augmented by a contractor-provided package consisting of an instructional video tape and a technical manual. I/O training averaged 14 hours and took place at sites designated by each test battalion. After an initial hit or miss approach to GUARDFIST I exercise sequence, crews settled on a strategy of starting on group exercise 1.1 and progressing as far as possible; thus, no crews trained using the last three (more complex) groups of exercises in progressive sequence. All main gun firing was scheduled by the separate test battalions. The South Carolina battalion scored their own tank crews on TT VII, and evaluators from each unit's Regular Army host battalion scored TT VIII. The number and type of TT VIII engagements, amounts and type of ammo fired, and ranges varied across the test battalions.

g. Statistical Methods: TT VIII scores were combined (day and night) and averaged to obtain three measures of live-fire performance: (1) mean engagement points score, (2) mean crew cuts score, and (3) mean net points score. The mean scores were compared by group, company, and battalion to assess transfer of training (i.e., did crews trained with GUARDFIST I show improved TT VIII performance over crews not trained with the device).

h. Stage of Training: Annual gunnery density.

i. User Acceptance or Attitude: After I/Os from both ARNG battalions completed their GUARDFIST I training, a questionnaire was administered to collect user opinions and comments on the operational features of the GUARDFIST I I/O control station.

5. Discussion:

a. Major Findings:

(1) The training of I/Os on GUARDFIST I revealed that (a) the exportable training package was not indicative of what is necessary for fielding, (b) I/Os were not able to perform 100% of the required critical tasks 100% of the time, (c) critical tasks were not identified to the test crewmen until after midway into the training sessions, and (d) the I/Os indicated that they had not received enough training to adequately operate the training system.

(2) The training of crewmembers on GUARDFIST I revealed that (a) TCs satisfactorily performed 13 of 14 engagement tasks, (b) gunners and loaders performed all engagement tasks offered by the device, and (c) drivers accomplished seven of 12 required tasks. Overall, 39 of 45 tasks were trainable on the device.

(3) GUARDFIST I does not replicate use of the TC's weapon, service ammo cannot be loaded, true range for all targets could not be determined, and the device does not allow for three range returns. Target ranges were within scenario parameters.

(4) GUARDFIST I did not interfere with normal operation of an M1 tank. The gunner's primary sight diopter lens, however, must be modified to mount on the M1IP tank.

(5) GUARDFIST I did not meet (a) the mean time between operational mission failure (6.2 hours vs. a required 323 hours), (b) operational availability (0.73 vs. required 0.83), and (c) the mean time to repair (48 minutes vs. required 30 minutes).

(6) GUARDFIST I logistical support concept was not fully tested and there was no maintenance allocation chart or system support package. Seven hardware and four software modifications had to be accomplished during the test.

(7) No safety-related accidents occurred during GUARDFIST I test, but a potential hazard existed with the installation of the diopter lens on the gunner's auxiliary sight.

(8) GUARDFIST I crewmembers indicated (a) a possible tripping hazard with cables on top of the turret, (b) heat build-up inside the turret, and (c) lack of a gas particulate filter system to blow air into the protective masks.

(9) No GUARDFIST I crews completed all device exercises. That is, no crews trained using device groups four, five, or six.

(10) Comparison of TT VIII scores in the South Carolina battalion revealed that (a) no tank crews qualified, (b) mean engagement point scores and mean total scores for GUARDFIST crews exceeded control crews in two of four companies, and (c) control crews performed better in crew cuts in three of four companies.

(11) Comparison of TT VIII scores in the North Carolina battalion revealed that (a) only one crew qualified (subcaliber), (b) mean engagement point scores and mean total scores for GUARDFIST crews exceeded control crews in all four companies, and (c) control crews had fewer crew cuts in three of four companies.

b. Authors' Conclusions:

(1) GUARDFIST I provided positive training transfer.

(2) GUARDFIST I did not interfere with the normal operation of an M1 tank.

(3) GUARDFIST I did not support tank crew procedures training.

(4) GUARDFIST I logistical support concept did not support its operational requirements.

(5) GUARDFIST I did not meet reliability, availability, and maintainability (RAM) requirements in an operational training environment.

(6) GUARDFIST I training program did not prepare I/Os to use and maintain the device in its operational environment (fixed facility).

(7) GUARDFIST I design had safety and health hazards.

(8) GUARDFIST I was not designed with regards to sound human factors engineering (HFE) principles.

c. Limitations:

(1) The Armor Training Device Macrostrategy (TC 17-12-7, Final Draft, U.S. Army Armor School, May 1988) indicates GUARD FIST I sessions are to be one hour during each MUTA and Annual Training, totaling 13 sessions per gunnery and maneuver year. However, the test permitted only 6 MUTA sessions for the South Carolina battalion and 7 for the North Carolina battalion.

(2) Main gun firing by the South Carolina battalion was conducted using TP-T and TPDS ammo instead of service ammo; thus, gunnery performance may not have accurately reflected the effect of GUARDFIST I training on crew gunnery.

(3) Due to subcaliber firing by the North Carolina battalion, TT VIII scores only approximated the impact of GUARDFIST I training on tank crew gunnery performance. Caliber .50 ammunition was used and not loaded from the ammo compartment; thus, altering engagement times and crew performance scores for each engagement. Half-scale ranges and full-scale targets were used also, and there is no probability of hit data under these conditions.

(4) The ability to determine (RAM) characteristics of GUARDFIST I was limited by the decision to allow seven hardware and four software system modifications during the test, and the lack of sufficient test hours.

d. Considerations:

(1) The crews were not assigned randomly to groups or matched between groups (crews were assigned by platoons). In addition, no analysis of variance (ANOVA) was performed on the crews' demographics (physical, military, or other personnel descriptions) within the groups to ensure they were from the same population (e.g., equal in gunnery performance before training).

(2) No reliability requirements were specified in the test plan; therefore, no test of reliability was conducted.

(3) No statistical comparisons among test group scores were performed because of extremely small sample sizes in each

comparative group. Groups were not combined to increase the size of the sample because of differences in range conditions (e.g., number and type of engagements) applied in testing.

(4) Gunnery training received by the GUARDFIST I crews during normal weekends was not controlled or monitored and may have attenuated their TT VIII performance.

(5) Only four tanks were used by the North Carolina battalion for the TT VIII test; thus, tank crews within a company were rotated onto the tanks mounting the Phoenix/Wallentine inbore device instead of using their assigned tanks.

6. Related Work:

a. DAEDALEAN, Incorporated (1990). Operator's manual Guard Unit Armory Device Full-Crew Interactive Simulation Training - Armor (GUARD FIST I). Columbia, MD: Author.

b. Department of the Army (1985). Tank combat tables M1 (Field Manual 17-12-1). Washington, DC: Author.

c. U.S. Army Armor School (1988). Armor Training Device Macro Strategy (TC 17-12-7). Fort Knox, KY: Author.

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24. Martellaro, H. C., Thorne, H. W., Bryant, J. A., & Pierce, M. A. (1985). Tank gunnery/Conduct of Fire Trainer-M1: training effectiveness analysis (TEA) (TRASANA-TEA-23-85). White Sands Missile Range, NM: U.S. Army TRADOC Systems Analysis Activity. (AD B097 355)

1. Topic Keywords: Armor; Tank Gunnery; Training Devices; U-COFT; Transfer of Training; Training Effectiveness Analysis.

2. Short Summary: This Training Effectiveness Analysis (TEA) involved one battalion of M1 tank crews that trained with and without the M1 U-COFT and fired different numbers of live main gun rounds during prequalification exercises (Tank Tables [TT] VI and VII). The objectives were to assess the effect 12 less rounds would have on TT VIII scores and whether U-COFT improves TT VIII performance. The results suggested (a) a trend towards better TT VIII performance of crews who fired more rounds (21 to 32) in contrast to crews who fired fewer rounds (0 to 20) in prequalification, (b) a trend towards better performance on TT VIII of crews who trained on U-COFT in contrast to crews who were not U-COFT trained, and (c) U-COFT training may partially offset effects on TT VIII performance of using a decreased number of prequalification rounds. Trends and possible directions for future research were examined, but no conclusions were presented.

3. Performing organization: U.S. Army TRADOC Systems Analysis Activity (TRASANA), White Sands Missile Range, White Sands, NM 88002-5502.

4. Approach: (Experimental)

a. Number of Groups: 4

b. Description of Groups:

(1) Group 1: M1 tank crews (tank commander [TC]/gunner pairs) who trained with the U-COFT and fired between 0-20 main gun rounds (TT VI and VII) prior to firing TT VIII.

(2) Group 2: M1 tank crews not trained with U-COFT who fired between 0-20 main gun rounds prior to firing TT VIII.

(3) Group 3: Same as group 1, except the tank crews fired between 21-32 main gun rounds prior to firing TT VIII.

(4) Group 4: Same as group 2, except the tank crews fired between 21-32 main gun rounds.

Note: Groups 1 and 2 averaged firing 11 rounds, groups 3 and 4 averaged firing 24 rounds.

c. Tests or Trials: TT VIII (seven day engagements and 3 night engagements). Different crews made up the day and night groups. Of the 56 crews, only 44 fired TT VIII. Final scoring was done by the 7th Army Training Command (7th ATC).

(1) Group 1: The number of crews who fired TT VIII was 21 day and 18 night.

(2) Group 2: The number of crews who fired TT VIII was seven day and two night.

(3) Group 3: The number of crews who fired TT VIII was four day and four night.

(4) Group 4: The number of crews who fired TT VIII was seven day and seven night.

d. Number of Different Types of Measures Used: 4

e. Description of Measures/Ratings: Four measures of TT VIII performance were examined: (1) score per task (average value for all tasks scored either day or night), (2) percentage of first round hits (number of first round hits divided by number of targets engaged), (3) percentage of targets hit (number of targets hit divided by total number of targets presented, and (4) percentage of targets hit per round expended (number of targets that would have been hit per 100 rounds).

f. Experimental Setting/Training Context: The TEA was conducted in an institutional and field setting using a hands-on training and testing approach. Each U-COFT crew received about 18.5 hours of training over nine days. The U-COFT program of instruction (POI) was specially designed and developed by General

Electric (GE), approved by the 7th ATC, and conducted by six GE trained Instructor/Operators (I/Os). The schedule for one day of U-COFT training was: (1) one hour observing another crew's U-COFT performance, (2) one hour of hands-on U-COFT training, (3) 20 to 30 minutes of debriefing based on U-COFT printouts, (4) a 30 minute break time, (5) one hour of hands-on U-COFT training, and (6) 20 to 30 minutes of debriefing based on U-COFT printouts. After U-COFT training, the U-COFT crews (units) returned to their home station and continued gunnery training. Depending on the company being trained, a period of one to three weeks passed between U-COFT training and the start of live fire gunnery.

g. Statistical Methods: The analysis of covariance (ANCOVA) was used to analyze the data. This statistical technique allows for the effect of one variable to be adjusted while examining the other variable (Winer, 1971). As such, criterion measurements were mathematically corrected for differences assumed to be caused by the U-COFT training or number of rounds fired by the crews. Because Table VIII includes day and night engagements, the day and night firing measures were evaluated separately.

h. Stage of Training: Annual gunnery training density.

i. Trainee Sophistication: Thirty-four TCs had 1-12 months in position, one had 13-15 months, and eight had over 18 months. Forty gunners had 1-12 months in position and three had over 18 months.

j. User Acceptance or Attitude: Two questionnaires were used to assess training perceptions. The first was administered during U-COFT training and consisted of 10 questions that were rated using a 5-point scale. The second was administered to 20 TCs and gunners from one company after Table VIII qualification (about three to four weeks after U-COFT training). It allowed crew members to write out responses to seven questions which were later grouped and tabulated into topics by TRASANA evaluators.

5. Discussion:

a. Major Findings:

(1) A trend towards better performance on TT VIII was found for crews who fired more rounds (21-32) as opposed to crews that fired fewer rounds (0-20) in prequalification gunnery. The group that fired more rounds scored higher on all four criterion measures than the group that fired fewer rounds; however, only (a) the percentage of first round hits and (b) the percentage of targets hit per round expended were statistically significant ($p<.05$).

(2) A trend towards better performance on TT VIII was found for tank crews who were trained on the U-COFT. The U-COFT group scored higher than the group not trained with U-COFT on all four measures, with the significant differences being percentage of first round hits and targets hit per round expended.

(3) Training on U-COFT may compensate for the effects of lower TT VIII performance attributable to a decreased number of prequalification rounds. Crews who had no U-COFT training and more rounds achieved higher scores per task (100 points each) than crews who were U-COFT trained and fired fewer rounds, but the difference did not carry over to three remaining measures.

(4) Armor crewmen trained on the U-COFT considered it to be an effective gunnery training device. Overall, most crewmen questioned rated the U-COFT training positively (excellent N=3, good N=9, fair N=3, poor N=0, bad N=0, no answer N=5).

(5) Most crewmen agreed that (a) the visual scenes in the U-COFT were good enough for training, (b) the U-COFT can help teach gunnery better than any other methods they currently have, and (c) they would like to spend more time in the U-COFT. Most crewmen disagreed that (a) the U-COFT controls have the same response as M1 tank controls and (b) U-COFT taught them a great deal that they didn't know about operating the M1 tank.

(6) The post questionnaire revealed that crewmen thought U-COFT improved (a) TC/gunner coordination, (b) identification skills, (c) fire commands, and (d) engagement techniques. Most thought (a) the power handles were too sensitive, (b) U-COFT was not realistic enough, and (c) no motion might affect TT VIII.

b. Authors' Conclusions: This study was conducted to examine trends and collect data as a foundation for future research, not to provide significant results or conclusions.

d. Limitations:

(1) The number of crews was too small, certain crews were restricted in the number of rounds they could fire, and poor weather prevented more crews from firing a full complement of rounds. Number of crews in each experimental condition differed.

(2) An in-depth analysis of units' home station gunnery training received prior to the study was not attempted; a brief examination considered it equivalent for all crews. As such, the authors were not certain if units in the different treatments were equivalent with respect to tank gunnery performance.

d. Considerations:

(1) The TT VIII scores are confounded; both first and second runs were used for calculating criterion measures. As per FM 17-12-1, tank crews that fail to qualify on their first Table VIII run are retested. During the retest, crews will generally fire only the engagements that they failed. The unit commander, however, may require the crew to refire the complete set of tasks or a subset of engagements (e.g., day exercise, night exercises).

(2) Live-fire performance tends to be unreliable because of measurement difficulties and the nature of the firing tasks.

Performance on any single engagement is, at best, only a rough indicator of proficiency (Hoffman, 1989).

(3) It is a commonly accepted practice that crews "G-2" the TT VIII course before making their qualification run. This knowledge plays a major role in target acquisition and results in much faster opening times and increased Table VIII points score.

6. Related Work:

a. Butler, W. G. (1982). Training developments study--M1 (Abrams) tank Unit-Conduct of Fire Trainer (TRASANA TEA 11-82). White Sands Missile Range, NM: U.S. Army TRADOC Systems Analysis Activity. (AD B954 521L)

b. Hoffman, R. G. (1989). Description and prediction of Grafenwoehr M1 Table VIII performance (ARI Technical Report 837). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

c. Winer, B. J. (1971). Statistical Principles in Experimental Design (2nd ed.). New York: McGraw-Hill Publishers.

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25. Morrison, J. E. (HumRRO), & Holding, D. H. (University of Louisville) (1990). Designing a gunnery training strategy (ARI Technical Report 899). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A226 129)

1. Topic Keywords: Armor; M1 Tank; Tank Gunnery; Training Strategies; Training Devices; VIGS; I-COFT.

2. Short Summary: This report investigated four methods that could be used to structure training, sequence training, select media/training devices, and allocate training time. The purpose was to (a) facilitate design of gunnery training strategies that would augment skill acquisition and transfer and (b) generate testable hypotheses about such training strategies. The four methods were applied to two prototypical problems in gunnery training. The first problem addressed the use of Videodisk Gunnery Simulator (VIGS) and the Institutional-Conduct of Fire Trainer (I-COFT) to train engagement skills. The second problem addressed the use of more than one device to train dissimilar platoon-level gunnery skills. The conclusion was that three methods adequately addressed both problems. The method for allocating training time between several training devices did not sufficiently address platoon-level gunnery training problems.

3. Performing Organization: Human Resources Research Organization (HumRRO), 5001 Eisenhower Avenue, Alexandria, VA 22314.

4. Approach: Analytical

5. Discussion:

a. Major Findings: The four training methods could be applied to gunnery training with reasonable results. The first two (structuring and sequencing) are guidelines for designing a training strategy rather than specific training procedures. The second two (selecting media and allocating training time) are based on identifying specific procedures that, if followed, will lead to the intended result. All four methods were applicable to the gunnery training problems involving VIGS and I-COFT devices. Methods for allocating training time, however, were not able to accommodate the multi-device platoon gunnery training problems.

b. Author's Conclusions: Training algorithms cannot be fully developed for instructional sequencing and structuring strategies, at the present time. That is, the series and order of steps and procedures one needs to know and perform to achieve the intended training results remain unspecified. Therefore, critical sequences and sets of steps have been developed that when followed may lead to the intended result.

c. Limitations: Several inherent difficulties arise when designing a tank gunnery training strategy. This report noted the difficulty in making judgements about the capabilities of training devices and strategies when such devices exist only in prototype form or when few clear-cut standards are available.

d. Considerations: Differences in individual ability level will create additional difficulties when designing a gunnery training strategy. Shlechter (1988) demonstrated that group computer-based training was more effective than use of individual computer-based training for training lower ability soldiers.

6. Related Work:

a. Hoffman, R. G. & Morrison, J. E. (1988). Requirements for a device-based training and testing program for M1 gunnery: Volume 1. Rationale and summary of results (ARI Technical Report 783). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A194 808)

b. Morrison, J. E., Drucker, E. H., & Campshure, D. A. (1991). Devices and aids for training M1 tank gunnery in the Army National Guard: A review of military documents and the research literature (ARI Research Report 1586). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A240 628)

c. Morrison, J. E. & Hoffman, R. G. (1988). Requirements for a device-based training and testing program for M1 gunnery: Volume 2. Detailed analyses and results (ARI Research Product 88-03). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A196 365)

d. Shlechter, T. M. (1988). The effects of small group and individual computer-based instruction on retention and on training lower ability soldiers (ARI Research Report 1497). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A203 793)

e. Turnage, J. J. & Bliss, J. P. (1990). An analysis of skill transfer for tank gunnery performance using TopGun, VIGS, and I-COFT trainers (ARI Technical Report 916). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A231 156)

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26. Morrison, J. E., Drucker, E. H., & Campshure, D. A. (1991). Devices and aids for training M1 tank gunnery in the Army National Guard: A review of military documents and the research literature (AR Research Report 1586). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A240 628)

1. Topic Keywords: Armor; Training Devices; Simulators; M-COFT; VIGS; TOPGUN; SIMNET; GUARDFIST I; HHT; ARNG; Skill Acquisition; Skill Retention; Performance Prediction; Training Transfer.

Short Summary: This report represents the initial step in development of a company level device-based tank gunnery training strategy for use by the Army National Guard (ARNG). Military/technical and research literature on six gunnery devices and aids were scrutinized for details pertaining to (a) training function, (b) use in training strategies, (c) effectiveness in terms of skill acquisition, retention, and transfer, and (d) prediction of performance. These devices were the Mobile-Conduct of Fire Trainer (M-COFT), Videodisk Gunnery Simulator (VIGS), Simulation Networking (SIMNET), Hand-held Tutor (HHT), Guard Unit Armory Device Full-Crew Interactive Simulation Trainer (GUARD FIST I), and TOPGUN. The literature review indicated that (a) each training device and aid effectively trained the intended functions/skills and (b) overlap of the skills trained could promote skill retention and transfer.

3. Performing Organization: Human Resources Research Organization (HumRRO), Alexandria, VA 22314

4. Approach: Analytical

5. Discussion:

a. Major Findings:

(1) Training functions: A review of the military and technical literature determined that types of skills trained on each device overlap. For example, TOPGUN and VIGS facilitated part-task gunnery skills training; GUARDFIST I and SIMNET supported full-crew interaction; and, GUARDFIST I and M-COFT

allowed TC/gunner training under normal and degraded conditions. These overlaps, instead of being "wasteful duplication", have been hypothesized to promote skill retention and transfer and, as noted by Hoffman and Morrison (1988), should be capitalized on to provide multiple gunnery training experiences.

(2) Tank gunnery training strategy: A variety of tank gunnery training strategies suggested which devices should be used to train specific armor skills and recommended different combinations of the 6 devices for different stages of training (Hoffman & Morrison, 1988; Morrison & Holding, 1990; U.S. Army Armor School, 1990). Battlesight, the predecessor of TOPGUN, was originally conceived as an informal/recreational training device. TOPGUN has been recommended to train basic gunner skills (Hoffman & Morrison, 1988) and Reserve Component armor crewmen (Hart, Hagman, & Bowne, 1990). However, TOPGUN has (a) not advanced beyond the research technology stage, (b) not been fielded as a tank gunnery training device, and (c) not been incorporated into the Armor Training Strategy (U.S. Army Armor Center, 1990). VIGS was the first gunnery training device, discussed by Morrison, et al., that has been incorporated into the gunnery cycle (U.S. Army Armor Center, 1990). As proposed for the ARNG, VIGS was to be used 1 hour during weekend drills, 1 hour before M-COFT training sessions, and during additional training sessions. The M-COFT was proposed for Reserve Component (RC) and ARNG sustainment training (U.S Army Armor Center, 1990). GUARDFIST I was proposed for preparation for qualification tests (Tables IV, VI, and VII). SIMNET was not recommended by Hoffman & Morrison (1988) for initial gunnery training, but proposed for advanced crew-level tactical training. The HHT, like TOPGUN, has not been incorporated into the Armor Training Strategy (U.S. Army Armor Center, 1990).

(3) Skill acquisition: Several empirical studies have determined the effectiveness of the six gunnery training devices in terms of skill acquisition. Research has demonstrated that TopGun, VIGS, M-COFT, and HHT contribute strongly to armor skill acquisition. To date, however, no empirical data exists on the skill acquisition capabilities of either the GUARDFIST I device or SIMNET.

(4) Skill retention: The authors reported that no empirical studies have investigated the effectiveness of TOPGUN, VIGS, GUARDFIST I, SIMNET, or the HHT with respect to skill retention. However, one report published since then (Lampton, Bliss, & Meert, 1992) indicated that tank gunnery skills on VIGS were retained marginally ($p=.061$) over a 10 week retention interval after initial training. As noted by the authors, the small number of participants in the retention testing greatly limited the power of the analyses and impeded evaluation of the effects of the experimental treatments on retention. Some evidence (Hughes, Butler, Sterling & Bergland, 1987) suggested that the U-COFT aids skill retention. However, Hughes et al. findings have been questioned on grounds that the amounts of sustainment training were not experimentally controlled between

crews during the retention interval. More empirical research remains to be done to determine the relationships between current tank gunnery training devices and skill retention.

(5) Transfer of training: The authors noted the importance of proving that skills acquired during training on one device will transfer to other devices and to actual equipment. Transfer of training research has not yet provided definitive evidence on this issue. Some evidence of training transfer has been found for the following: from TOPGUN to U-COFT; from VIGS to TOPGUN; from VIGS to dry-fire; from M-COFT to live-fire; and from tactical training on SIMNET to field performance. As of yet, no evidence has documented transfer with GUARDFIST I or HHT.

(6) Performance prediction: Some research evidence was found which indicated that performance on gunnery devices can be used to predict performance on other training devices and live-fire. The findings were summarized as follows with respect to performance prediction: TOPGUN predicts U-COFT; VIGS predicts U-COFT but not TOPGUN; M-COFT matrix achievement predicts live-fire; and performance on SIMNET predicts field measures of tactical performance. No data were available for the HHT.

b. Authors' Conclusions:

(1) From a learning standpoint, the overlap between tank gunnery training devices may be useful in promoting the retention and transfer of skills. From a practical standpoint, the ARNG may not have some of the devices described in this report.

(2) Because of the M-COFT's ability to address gunnery objectives not trained by other devices, the M-COFT will assume a central role in the training strategy for ARNG units with support and supplement coming from the other devices.

(3) Additional training aids that can support training critical knowledges that are related to M1 gunnery need to be developed and tested.

c. Limitations: NA

d. Considerations:

(1) Much of the research accomplished with the VIGS and Topgun training devices was performed using different versions of the prototype devices. Given the operational problems apparent with each device at that time, as well as possible shortcomings of the research, the summary of findings presented by the authors should be considered with caution.

(2) Although some device-based research suggested that gunnery skills transferred to other devices, dry-fire, or live-fire gunnery, the types of skills that transfer from one device to another (or to the tank itself) and the practice conditions that facilitated transfer of skills have not been identified.

6. Related Work:

a. Campshure, D. A. (1990). Devices and aids for training M1 tank gunnery in the Army National Guard: A detailed analysis of training requirements (HumRRO Draft Interim Report). Alexandria, VA: Human Resources Research Organization (HumRRO).

b. Hoffman, R. G., & Morrison, J. E. (1988). Requirements for a device-based training and testing program for M1 gunnery: Volume 1. Rationale and summary of results (ARI Technical Report 783). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A194 808)

c. Hughes, C. R., Butler, W. G., Sterling, B. S., & Bergland Jr, A. V. (1987). M1 Unit Conduct-of-Fire trainer (TRAC-WSMR-TEA-16-87). White Sands Missile Range, NM: Department of the Army, U.S. Army TRADOC Analysis Command. (AD BII3 298)

d. Morrison, J. E., & Holding, D. H. (1990). Designing a gunnery training strategy (ARI Technical Report 899). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A226 129)

e. U.S. Army Armor Center (1990). Armor training strategy (Draft Special Text 17-12-7). Fort Knox, KY: Author.

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27. Morrison, J. E. & Walker, S. W. (1990). The effects of mental practice on tank gunnery performance (ARI Technical Report 873). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A219 916)

1. Topic Keywords: M1 Tank; Gunnery Training; Training Devices; I-COFT; Mental Practice; ASVAB; Internal/External Locus of Control Scale; Betts' Questionnaire Upon Mental Imagery (QMI).

2. Short Summary: This research (a) examined the effect of mental imagery on gunnery skill acquisition and (b) attempted to identify individual differences that related to the use and effectiveness of mental imagery. Ninety armor trainees (Military Occupational Specialty (MOS) 19K) from three One Station Unit Training (OSUT) platoons participated in the research prior to scheduled I-COFT gunnery training. Three measures of individual differences were collected on each soldier followed by an I-COFT pretest. Soldiers in the experimental group were instructed to use mental practice in addition to their normal I-COFT training, while soldiers in the control group received only I-COFT gunnery training. Following seven hours of gunnery training on the I-COFT, all soldiers were given an I-COFT gunnery skills posttest. After the posttest, soldiers in the experimental group completed a questionnaire designed to assess their use of mental practice.

The results indicated that (a) all soldiers' gunnery performance (speed, accuracy, and hit rate) significantly improved from I-COFT pre- to posttest, (b) soldiers who were not in the mental practice group mentally rehearsed (spontaneously) without being instructed to do so, and (c) mental practice failed to improve speed or accuracy of gunnery performance on the I-COFT.

3. Performing organization: Human Resources Research Organization (HumRRO), 5001 Eisenhower Avenue, Alexandria, VA: 22314.

4. Approach: Experimental

a. Number of Groups: 2

b. Description of Groups:

(1) Experimental Group: This group consisted of two platoons (N=30, N=31) of armor trainees (MOS 19K) from an OSUT company. The 61 soldiers received instructions and training in how to mentally practice tank gunnery, in addition to gunnery training on the I-COFT. The mental rehearsal instructions were to mentally picture yourself going through all the actions that you would perform to successfully destroy a threat target on the I-COFT. Soldiers in this group mentally rehearsed the engagement for five minutes.

(2) Control Group: This group consisted of one platoon (N=29) of armor trainees from the same OSUT company. The 29 soldiers received only normal gunnery training on the I-COFT.

c. Tests or Trials: The 90 soldiers were trained and tested in Week 9 of their 14-week training cycle. During Week 9, each soldier received 12-hours of I-COFT familiarization training and seven hours of integrated gunnery skills training on the I-COFT. The I-COFT pre- and posttest was a 17-minute gunnery exercise composed of 10 engagements of single main gun or single coaxial machinegun targets using precision gunnery techniques. The 10 engagements consisted of stationary and moving target and own tank conditions.

d. Number of Different Types of Measures Used: 2

e. Description of Measures/Ratings:

(1) Individual Difference Measures: Three measures of individual differences were collected prior to I-COFT training. They were: (a) General Technical (GT) score from the Armed Forces Vocational Aptitude Battery (ASVAB), which were retrieved from unit records; (b) Internal/External Locus of Control Scale; and (c) Betts' Questionnaire Upon Mental Imagery (QMI).

(2) Gunnery Measures: Three measures of tank gunnery performance were collected from the soldiers' I-COFT pre-posttest; firing rate, hit probability, and hit rate. Firing

rate (speed) was the number of rounds fired per minute of target exposure time. Hit probability (accuracy) was the proportion of targets hit divided by the total number of targets presented. Hit rate (speed and accuracy) was the number of target hits achieved per minute of target exposure.

f. Experimental Setting/Training Context: All training and testing was conducted in an institutional training facility using 24 I-COFT simulators and 22 qualified Instructor/Operators (I/Os) allocated to train OSUT armor trainees.

g. Statistical Methods: T-tests, Analysis of Variance (ANOVA), Analysis of Covariance (ANCOVA), Chi-Square tests, and regression analyses were conducted on the individual difference and gunnery performance data.

h. Stage of Training: Basic Armor Training

i. Trainee Sophistication: Novice

5. Discussion:

a. Major Findings:

(1) Both groups significantly improved their speed, accuracy, and hit rate from I-COFT pretest to posttest.

(2) The experimental group performed significantly better than the control group on all three gunnery measures on the I-COFT pretest, but not on the I-COFT posttest.

(3) Soldiers in the control group reported mentally rehearsing gunnery without being instructed to do so.

(4) The Internal/External Locus of control scale did not predict the use of mental practice techniques.

(5) Soldiers who had higher GT scores from the ASVAB performed significantly better on all three gunnery measures.

b. Authors' Conclusions:

(1) Individuals with higher ability are more likely to (spontaneously) mentally rehearse in an appropriate manner.

(2) Conclusions about the effects of mental practice on gunnery performance are difficult to identify from these results because I-COFT pretest differences existed between experimental and control groups and (b) soldiers in the control group reported using mental practice without being instructed to do so.

c. Limitations:

(1) The soldiers in the compared groups were not matched by ability or randomly assigned to groups.

(2) The experimental group differed significantly from the control group on all three I-COFT pretest measures of gunnery performance. Also, the control group used mental practice even though they were not instructed to do so.

d. Considerations: The experimental (N=61) and control groups (N=29) had disparate numbers of armor trainees. However, the authors explained that the two platoons assigned to the experimental condition were scheduled to mentally practice in two different contexts. However, when logistical problems could not be overcome, both platoons were included in the same condition.

6. Related Work:

a. Druckman, D., & Swets, J. A. (Eds.) (1988). Enhancing human performance: Issues, theories, and techniques. Washington, DC: National Academy Press.

b. Richardson, A. (1967). Mental practice: A review and discussion (Part I). Research Quarterly, 38, 95-107.

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28. Rapkoch, J. M. II., & Robinson, F. D. (1986). Concept evaluation program of gunnery training devices (Final Report 6CEP342). Fort Knox, KY: U.S. Army Armor and Engineer Board. (AD B104 075)

1. Topic Keywords: Armor; Tank Gunnery; Training Devices; BT-41; MILES-TSV; U-COFT; Performance Testing; Tank Table VIII.

2. Short Summary: This Concept Evaluation Program (CEP) was designed to assess the capability of three M1 tank gunnery devices to substitute for firing main gun ammunition on Tank Tables (TT) VI and VII without degrading proficiency on TT VIII. Four M1 tank companies from a battalion were assigned to train TT VI and VII using (a) live-fire (baseline), (b) Unit-Conduct of Fire Trainer (U-COFT), (c) Multiple Integrated Laser Engagement System-Thru-Sight Video (MILES-TSV), and (d) the BT-41. Tank crews consisted of the tank commander (TC) and gunner only. The results revealed (a) BT-41 and MILES-TSV companies fired TT VIII as well as the live-fire company, but the U-COFT company scored significantly lower than the live-fire company on TT VIII; (b) U-COFT provided crews with excellent technical skill proficiency, but was limited with respect to target acquisition training; (c) BT-41 provided crews with precision gunnery training, but loader interaction was limited; (d) MILES-TSV simulated main gun firing well (but not precisely), provided an excellent after-action review (AAR) capability, but limited the loader interaction; and (e) crewmen indicated that U-COFT and MILES-TSV would be useful and that BT-41 would be of some use in training new crewmembers.

3. Performing Organization: U.S. Army Armor and Engineer Board, Fort Knox, KY 40121-5470.

4. Approach: Experimental

a. Number of Groups: 4

b. Description of Groups: All four groups were from same the same M1 tank battalion.

(1) Live-Fire (Baseline): The subjects were 14 crews within company who fired TT VI and VII using live main gun train , ammunition.

(2) U-COFT: The subjects were 14 crews within a company who fired U-COFT exercises that matched TT VI and VII tasks.

(3) BT-41: The subjects were 14 crews within a company who fired TT VI and VII using the BT-41, an Eye-Safe System Laser Rangefinder (ESSLR), and Laser Target Interface Devices (LTIDs) to provide target effect.

(4) MILES-TSV: The subjects were 14 crews within a tank company who fired TT VI and VII using MILES, LTIDs to provide target effect, and the TSV results for conducting AAR's.

c. Tests or Trials: The crews fired TT VIII (five day and five night engagements), one time only, on the same range and under similar conditions. TT VIII was conducted in accordance with FM 17-12-1 (draft), except exercise timing and scoring was terminated at 40 seconds. Test directorate personnel scored TT VIII to ensure consistency in test procedures and scoring.

d. Number of Different Types of Measures Used: 3

e. Description of Measures/Ratings: The three TT VIII measures were: (1) percent engaged (number of targets engaged/number of targets possible), (2) target hit percentage, (number of target hits/number of targets engaged), and (3) average engagement time (in seconds) for first target.

f. Experimental Setting/Training Context: This CEP was conducted in an institutional and field setting using a hands-on training and testing approach. Prior to testing, each crewmember completed a detailed demographics questionnaire. Armed Services Vocational Aptitude Battery (ASVAB) scores were provided to the test directorate. To ensure baseline proficiency in tank crew fundamentals, each company administered the Tank Crew Gunnery Skills Test (TCGST) to all tank crew members and each crew completed TT IV, a Tank Crew Proficiency Course (TCPC), in a dry-fire mode. All soldiers were required to take the TCGST until they passed all tasks. In addition, each crew was required to conduct the TCPC until they had successfully completed it. On completion of TT IV, the crews were allowed 48 hours to train on the preliminary gunnery tables (TT VI and VII) using their respective gunnery devices (U-COFT, BT-41, and MILES-TSV) or live-fire ammunition. A special program of instruction (POI) was provided for training the tables with each device. After crews

in the live-fire group (baseline) completed training, all crews fired TT VIII using main gun ammunition.

g. Statistical Methods: Statistical t-tests were used to determine if the baseline (live-fire) groups' TT VIII scores differed from the scores of the three training device groups. TT VIII performance was examined by (1) group (live-fire, U-COFT, BT-41, MILES-TSV); (2) individual tasks (five day, five night); (3) weapon system (main gun, machine gun, combined), and (4) time of day (day, night, combined). All demographics and ASVAB scores were compared to determine if there were any statistical differences between each company in each demographic and ASVAB category.

h. Stage of Training: Annual gunnery training density.

i. User Acceptance or Attitude: An opinion questionnaire was administered to subjects in tank company groups at the end of TT VIII to assess their perceptions of the training devices.

5. Discussion:

a. Major Findings:

(1) No significant differences were detected between each company in each demographic and ASVAB category, in the quality of the TCGST among the companies, and in the number of retrials (less than 6%) between companies. All companies were declared equivalent at the end of TT IV. The average height, weight, and General Technical (GT) scores of the battalion were found typical of M1 armor crewmen population which is 68.7 inches, 162 pounds, and 103, respectively.

(2) The M1 U-COFT was found to provide excellent TC and gunner critical gunnery skills training. However, due to the 32 degrees day and 16 degrees night engagement area (as opposed to the 80-degree target engagement area on TT VIII), the device was limited in terms of target acquisition and observation of target hit training. On average, U-COFT crews took 3 seconds longer to engage the first target on TT VIII than the slowest of the other companies.

(3) The BT-41 provided crews with a precision gunnery capability and provided effective gunner training. However, the printout cannot be used as a debriefing tool by itself and loader interaction was limited.

(4) The MILES-TSV simulated main gun firing, but not in a precision manner. Negative training occurred because the wide laser beam allowed the gunner to "destroy" a target even though he may have not had a proper reticle lay on the target. Loader interaction was limited. The AARs provided by the TSV are an extremely effective training and critiquing capabilities tool.

(5) The BT-41 and MILES-TSV companies fired TT VIII as well as the live-fire company. However, the U-COFT company scored significantly lower than the live-fire company on TT VIII.

(6) Crewmen indicated that U-COFT and MILES-TSV would be useful and BT-41 would be some use in training new crewmembers.

b. Author's Conclusions:

(1) The U-COFT alone cannot bring crews up to TT VIII proficiency; thus, it cannot be recommended for use in modeling the gunnery tables as a shortcut for sustainment training. On the other hand, it can provide crews with critical gunnery skill training and it reinforces skills for sustainment training.

(2) The BT-41 was a difficult device to boresight. In addition, problems emerged when the ESSLR was not available or was used at ranges beyond 1000 meters; i.e., crews expressed unnecessary concern when using the device without protective goggles, even when the ESSLR was installed.

(3) The MILES-TSV provided excellent AARs. However, because the TSV is mounted externally on the M1, several units malfunctioned in adverse conditions (e.g., dust, rain, etc.).

c. Limitations:

(1) Based on the strength of the test battalion, full tank crews were not stabilized. Only the TC and gunner were unique to each crew. As such, loaders and drivers performed their duties on more than one tank during TT VIII firing.

(2) An absence of a loader's program of instruction for MILES-TSV, BT-41, and U-COFT precluded evaluation of different loader training methods that could be used.

(3) The amount of training given some crews varied. In most cases, crews retrained on TT VI and VII until they reached their proficiency criterion.

d. Considerations:

(1) A major problem in training device testing has been the frequent use of samples that are too small in relation to the variability of performance (N=14), so that the statistical power to detect differences of a reasonable size has been inadequate.

(2) Live-fire performance tends to be unreliable because of measurement difficulties and the nature of the firing tasks. Performance on any single engagement is, at best, only a rough indicator of proficiency (Hoffman, 1989).

(3) The crews were not randomly assigned to the live-fire (baseline) and training device groups. Although there were no differences between groups based on an analysis of demographic

data, the effects of prior TT VIII performance or differences in command emphasis during training cannot be determined.

(4) In TT VIII scoring, penalty points are subtracted from a crew's gunnery score for each task because of "crew cuts" (e.g., failed to adhere to required task conditions [30 point penalty], failed to adhere to basic safety precepts [10 point penalty]). Crew cuts during the test was extremely low; i.e., only 42 crew cuts for 560 tasks fired by the test battalion.

6. Related Work:

a. Department of the Army (1983). Operator's manual for Multiple Integrated Laser Engagement System (MILES), simulator system, firing, laser: M82 (Technical Manual 9-1265-373-10-1). Washington, DC: Author.

b. Department of the Army (1984). Tank combat tables M1 (Field Manual 17-12-1, Final Draft). Washington, DC: Author.

c. Hoffman, R. G. (1989). Description and prediction of Grafenwoehr M1 Table VIII performance (Technical Report 837). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD B136 331)

d. U.S. Army Armor School (1985). M1 Unit-Conduct of Fire Trainer (U-COFT) training device support package (Field Circular 17-12-7-1). Fort Knox, KY: Author.

e. U.S. Army Armor School (1985). Operator's Manual for M1 Thru-Sight Video (TSV) (Draft). Fort Knox, KY: Author.

f. U.S. Army Training and Doctrine Command (1986). Test design plan for the Concept Evaluation Program of Gunnery Training Devices (TRADOC TRMS No. 6-CEP342). Fort Monroe, VA: Author.

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29. Robinson, F. D., & Angotti, M. J. (1987). Initial operational test and evaluation of the Tank Precision Gunnery Inbore Device (TPGID) (Final Report 87-OT-AEBD-1429). Fort Knox, KY: U.S. Army Armor and Engineer Board. (AD B115 072)

1. Topic Keywords: M1A1 Tank; Tank Gunnery; Subcaliber Training Device; TPGID; Training; Test and Evaluation

2. Short Summary: Two M1A1 tank test battalions were divided into two groups, by company; a Tank Precision Gunnery Inbore Device (TPGID) group and a baseline group. The TPGID group conducted Tank Table (TT) VI and VII for all main gun live-fire engagements, except the calibration exercise of Table VI, using TPGID. The baseline group conducted the same two tank tables using full caliber main gun training ammunition. Both groups

fired the machine gun portion of the tables using their organic machine guns. After completion of these tables, both groups fired a TT VIII. The results revealed that the averages of the TT VIII scores were equivalent statistically. At the 80 percent confidence level, no statistical difference was indicated between the scores of the two groups. Although the difference between groups was nearly significant statistically, subjective ratings indicated that TPGID was not a fully satisfactory substitute for firing full caliber main gun rounds.

3. Performing Organization: U.S. Army Armor and Engineer Board (AEBD), Fort Knox, KY 40121-5470.

4. Approach: Experimental

a. Number of Groups: 2

b. Description of Groups:

(1) Subjects in TPGID Group: Four tank companies (56 crews, 224 personnel) fired TT VI and VII using TPGID and their normal tank machine guns.

(2) Subjects in Baseline Group: Four tank companies, (57 tank crews, 228 personnel) fired TT VI and VII using standard 120-mm training ammunition and their normal tank machine guns.

c. Tests or Trials:

(1) Subjects in TPGID Group: TT VIII (seven day and three night engagements).

(2) Subjects in Baseline Group: Same.

(3) Both Groups: The companies in each of the two test battalions were randomly selected by the testing directorate. No difference was indicated in any of the two groups' demographics (physical, military, or other personnel descriptions) at the 95% confidence level. The two groups were allocated the same number of rounds (TPGID or 120 mm) of training ammunition. Both groups fired TT VIII on Range 117 of Grafenwoehr Training Area, using the same scoring criteria and scoring agency (7th Army Training Center). All tanks were calibrated prior to the start of TT VIII to ensure each individual tank's firing system was operating as designed. Due to heavy fog and otherwise inclement weather, one tank company was prevented from firing all their crews on TT VII. Consequently, only three companies' (42 tank crews, 168 soldiers) TT VIII results were used for evaluation.

d. Number of Different Types of Measures Used: One.

e. Description of Measures/Ratings: TT VIII scores (which are based on time, target hits, and crew penalty points), as per FC 17-12-1A1, FM 17-12-1, and task identifications listed.

f. Experimental Setting/Training Context: The battalions had just completed "rollover" and neither had fired their M1A1 tanks before the start of the test. All tank gunnery training and TT VI and VII scenarios were established by the two test battalion training programs and conducted on Ranges 10, 112, and 132. Each company scored their own crews on TT VI, and the parent battalion scored the crews' TT VII. The only training requirement was for each crew to complete at least one TT VI and VII prior to firing TT VIII. Extra runs were based on the unit's training strategy and resources. The amounts of ammunition and range time varied across battalions, but all companies received equal amounts of 35-mm TPGID ammo or 120-mm ammunition as well as machine gun ammunition.

g. Statistical Methods: A one-directional t-test was performed on the summed TT VIII scores of the two test groups. An analysis of variance (ANOVA) was performed on the companies within the groups to ensure they were from the same population (95 percent confidence level). Given no significant differences in the overall TT VIII scores between the companies within a test group, scores were combined for a total group score and average, and compared. Comparisons, using one-directional t-tests, were performed on each individual task and total day and night tasks.

h. Stage of Training: Annual gunnery density.

i. Trainee Sophistication: Intermediate to high.

j. User Acceptance or Attitude: After each TPGID tank crew completed TT VIII, a questionnaire was administered to collect user opinions on the ability of TPGID to simulate blast, flash, noise, smoke, sight displacement, tracer, and burst indication in training. A 7-point rating scale was used with "4" being a "satisfactory" rating. User opinions were also collected on problems with the system, possible improvements, benefits, drawbacks, and potential uses.

5. Discussion:

a. Major Findings:

(1) The averages of TT VIII scores of the TPGID group (821.26) and baseline (live-fire) group (840.79) were found statistically equivalent at the 80 percent confidence level.

(2) The average response rating of TPGID as a training device (3.42) was "less than satisfactory." This rating was given by the participants after responding to questions on system problems, improvements, benefits, drawbacks, and potential use.

(3) TPGID failed to meet the criterion of having 75% of the participants determine that the sensory cues provided for training were satisfactory. Except for tracer indication, they indicated that TPGID did not provide adequate feedback for blast, flash, noise, smoke, sight displacement, or burst indication.

b. Authors' Conclusions:

(1) TPGID trained crews can conduct realistic precision and degraded mode main gun firing and target acquisition using the same tank fire control system that they would use with full caliber main gun ammunition.

(2) All crew drill actions with the TPGID are the same as those used for full caliber ammunition. Since there are no changes to the fire control system, the crews must acquire the target, determine the correct range, select the correct ammo, and engage the target with the same procedures used for full caliber ammunition.

(3) The averages of the TT VIII scores of both groups were statistically equivalent at an 80% confidence level.

c. Limitations:

(1) Separation in time between the two test battalions was 20 days. With the test conducted in two phases, the weather conditions experienced during the second test battalions' gunnery density was significantly different from that during the first.

(2) Home station gunnery training was not controlled or monitored and may have affected the test units' performance.

(3) Only TPGID HEAT ammunition was available for the test. As a result, all TT VI and VII engagements with the TPGID were fired with TPGID HEAT ammunition. Tank target engagements specifying SABOT were fired with HEAT ammunition, but the actions were the same as those that would have been taken if SABOT were available.

(4) Only four TPGIDs were available for the test; thus, crews within a company were rotated onto the tanks mounting the TPGIDs to conduct their tables instead of using their assigned tanks. The devices were rotated between the two test companies in each test battalion as the two test companies conducted tank gunnery tables.

(5) No reliability requirements were specified in the test plan, nor was a reliability waiver requested by the test proponent; thus, no testing toward reliability was conducted.

(6) During the test period, two firing days were lost due to heavy fog and otherwise inclement weather. As a result, two tank companies (one per group) could not fire all their crews on TT VII.

(7) Training time and the limited range availability at Grafenwoehr Training Area restricted each test battalion to four firing days per table or one day per company, per range.

d. Considerations: Based on a discussion by Al Pomey (Operations Research System Analyst (ORSA), Weapons Department, U.S. Army Armor School, Memorandum for Record, April 20, 1992), given the test sample size (N=42) and confidence level (80 percent), a threshold value of 20.33 (versus 19.53) or greater was required to have obtained statistical significance. That is, had the average Table VIII score for the baseline group been one point higher, or the TPGID group one point lower, the results would have revealed that TPGID was not an adequate substitute for live-fire main gun preparatory firing. This also would have been the case had the same average scores and standard deviations been obtained with sample size of 46 versus 42 crews.

6. Related Work:

a. Pomey, A. H. (1992). Memorandum for Record, April 20, 1992.

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30. Rose, A. M., Wheaton, G. R., Leonard, R. L., Fingerman, P. W., & Boycan, G. G. (1976). Evaluation of two tank gunnery trainers (ARI Research Memorandum 76-19). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A082 954)

1. Topic Keywords: Armor; Tank Gunnery Training; Training Devices; 3A102B Laser; M73 Coax MG; Training Transfer; Fidelity

2. Short Summary: This research evaluated the effectiveness of two tank gunnery training devices (3A102B laser and M73 Coaxial Machine Gun, single shot mode) for preparing gunners to track and fire the M60A1 main gun. Six groups of M60A1 trainees (N=22 per group) were trained to a 30%, 50%, or 70% proficiency level using the laser or machine gun training device. A control group (N=22) was given no simulated fire training. Following training, all groups live-fired 12 main gun rounds at a moving tank target silhouette from an M60A1 tank. The results from the transfer test revealed that (a) firing accuracy improved over the transfer session and (b) the two most highly trained groups (trained to 70% proficiency level) were significantly more accurate than the control group. Based on the transfer test results, performance during transfer did not differ with respect to the type of device on which training was received. The differences in performance were attributed to amount rather than kind of training.

3. Performing Organization: American Institutes for Research (AIR), 1055 Thomas Jefferson Street, NW, Washington, DC 20007.

4. Approach: Experimental

a. Number of Groups: 7

b. Description of Groups: The subjects were 154 M60A1 (MOS 11E10) trainees assigned to seven groups: (1) three 3A102 laser device groups, (2) three M73 coaxial machine gun, or (d) one no

training (control) group. To create seven equivalent groups of 22 each, trainees were matched according to Army status, prior service, and General Technical scores on the Army Classification Test. The 30%, 50%, or 70% proficiency levels for the training groups was arbitrary. That is, training ceased when a trainee met the proficiency level during 20 consecutive trials.

(1) Group 1: Trained with the 3A102B laser device to a 30% proficiency level.

(2) Group 2: Trained with the 3A102B laser device to a 50% proficiency level.

(3) Group 3: Trained with the 3A102B laser device to a 70% proficiency level.

(4) Group 4: Trained with the M73 coaxial machine gun to a 30% proficiency level.

(5) Group 5: Trained with the M73 coaxial machine gun to a 50% proficiency level.

(6) Group 6: Trained with the M73 coaxial machine gun to a 70% proficiency level.

(7) Group 7: No simulated fire training (Control Group).

c. Tests or Trials: The performance criterion was a live-fire posttest in which each trainee fired 12 main gun rounds from a stationary M60A1 tank at a moving tank target silhouette.

d. Number of Different Types of Measures Used: 4

e. Description of Measures/Ratings: The measures were: (1) number of training trials to criterion, (2) percentage of hits on a live-fire transfer test, (3) misses on a live-fire transfer test; and (4) speed of firing on a live-fire transfer test.

f. Experimental Setting/Training Context: The research was conducted in an institutional and field setting using a hands-on training and testing approach.

g. Statistical Methods: Statistical t-tests, analysis of variance (ANOVAs), and arcsine and square root transformations were used to analyze the data.

h. Stage of Training: Novice.

5. Discussion:

a. Major Findings:

(1) Firing accuracy improved throughout the transfer test for all groups. There was significant difference among

groups with respect to speed of firing the first round once the target appeared.

(2) While gunnery accuracy improved over the transfer session and initial training accuracy was comparable for all groups, only the two most highly trained groups (Groups 3 and 6; 70% proficiency level) were significantly more accurate than the control group. There were no statistically significant differences with regard to speed.

(3) There was some evidence of negative transfer from the training devices. The built-in lead of the 3A102B laser device simulated flight time of a real shell fired at a moving target. When a target moved from left to right and the gunner's crosshairs were sighted on the center of the target, the burst would be displaced approximately 5 mils to the left (behind the target). However, the built-in lead was unidirectional with respect to target movement. When the target moved from right to left, the gunner would have to aim behind the target to get the burst to land on it. To avoid negative transfer, trainees only fired when the target was moving from left to right and simply tracked it when it moved right to left.

b. Authors' Conclusions: The most important determinant in positive transfer was amount of gunnery training received rather than the device on which training was provided. However, training with a faulty method (wrong lead) leads to poor performance transfer.

c. Limitations and considerations: The clear limitation of the research was the unidirectional lead built-in to the 3A102B laser device.

6. Related Work:

a. Wheaton, G. R., Rose, A. M., Fingerman, P. W., Korotkin, A. L., & Holding, D. H. (1976). Evaluation of the effectiveness of training devices: Literature review and preliminary model (ARI Research Memorandum 76-6). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A076 809)

b. Wheaton, G. R., Fingerman, P. W., Rose, A. M., & Leonard, R. L., Jr (1976). Evaluation of the effectiveness of training devices: Elaboration and application of the predictive model (ARI Research Memorandum 76-16). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A076 818)

c. Wheaton, G. R., Rose, A. M., Fingerman, P. W., & Boycan, G. G. (1976). Evaluation of three burst-on-target trainers (ARI Research Memorandum 76-18). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A076 820)

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31. Sigtenhorst, K. H., & Johnson, J. R. (1982). Final report of concept evaluation of institutional tank gunnery and missile tracking system (I-TGMTS) (TRADOC TRMS 2-CEP018). Fort Knox, KY: U.S. Army Armor and Engineer Board.

1. Topic Keywords: M60A1 Tank; Gunnery Training; Training Devices; I-TGMTS; M55 Laser; Cal .22; Training Effectiveness; Training Transfer; Concept Evaluation; TT VI.

2. Short Summary: The purpose of the concept evaluation program (CEP) was to (a) compare the relative effectiveness of the Tank Gunnery and Missile Tracking System (TGMTS) with cal .22 and M55 laser devices in providing initial gunnery training; (b) provide limited data on Reliability, Availability, and Maintainability (RAM) and logistic supportability of TGMTS in the institutional environment; (c) examine the instructor training required for effective use of TGMTS in institutional training; and (d) examine the safety and human factors for the TGMTS. A total of 85 basic armor training (BAT) soldiers trained on tank tables (TT) I-V on the TGMTS while 91 BAT soldiers (baseline group) trained on the same tables using the M55 laser and cal .22 devices. Both groups were then tested on a modified TT VI (day only) live-fire exercise. Video and event recording equipment were used with the TGMTS to ensure reliable performance measurements. The results indicated that (a) TGMTS, as measured by its training transfer on TT VI, was as effective as the M55 laser and cal .22 devices in providing initial tank gunnery training, (b) the TGMTS trained soldiers had significantly faster precision engagement times (average of 1.5 seconds), and (c) non-TGMTS trained soldiers applied a significantly more accurate subsequent fire command change to their sight (average of .38 mils). A record of TGMTS malfunctions during testing indicated that the equipment was reliable. User comments about the TGMTS device were positive.

3. Performing Organization: U.S. Army Armor and Engineer Board (AEBD), Fort Knox, KY 40121-5470.

4. Approach: Experimental

a. Number of Groups: 2

b. Description of Groups: The test participants were entry-level soldiers, Military Occupational Special (MOS) 19E, who were attending BAT at Fort Knox. The soldiers were randomly selected from 10 BAT companies and assigned to either a baseline or TGMTS training group. All BAT soldiers trained with their company up to the ninth week of training. During weeks 9 and 10, the two groups were trained on TT I-IV and then tested on a modified TT VI (day only) live-fire exercise.

(1) Baseline Group: This group consisted of 91 BAT soldiers who used the M55 laser and cal .22 to train TT I-IV.

(2) TGMTS Group: This test group consisted of 85 BAT soldiers who used the TGMTS device to train TT I-IV.

c. Tests or Trials: A modified TT VI (day only) live-fire test was used to determine if there was a significant difference between the training transfer of the TGMTS and currently used gunnery training (baseline) methods. The modified TT VI live-fire exercise consisted of eight engagements which included a combination of own stationary tank versus single stationary and moving targets, located at short and long ranges, with HEAT or TPDS-T ammunition, using precision and battlesight techniques, and under NBC conditions. Except for two engagements, only one round was fired per engagement.

d. Number of Different Types of Measures Used: 4

e. Description of Measures/Ratings: The primary criterion measures were (1) gunner's lay accuracy (i.e., comparing the gunner's aim with a "perfect" sight picture) and (2) gun time (i.e., time from when the gunner announced "identified" until engagement was completed) during live-firing of modified TT VI. Secondary measures of effectiveness (MOE) were (1) target effect (hit-miss) and (2) completion of gunner crew duties (i.e., main gun switch on, correct ammo indexed, target identified and announced, announcing "on the way", and announcing sensing).

f. Experimental Setting/Training Context: This research was conducted in an institutional and field setting using hands-on training and testing. In Phase I, BAT students received gunnery training with their assigned units in the classroom with limited hands-on training. In Phase II, the test group trained for TT I-IV using the TGMTS and the baseline group trained using the M55 laser and cal .22 devices. In Phase III, the test and baseline groups completed a modified TT VI (day only) live-fire exercise controlled by the test directorate. At the conclusion of this exercise the soldiers of both groups returned to their assigned units and completed training for TT VIIC.

g. Statistical Methods: The data were analyzed using the Statistical Package for the Social Science (SPSS). Both the Mann-Whitney and Kolomogorov-Smirnov nonparametric tests were used to analyze the non-normal distribution of gunner time and radial error data. Chi-square test were also performed to analyze hit-miss data for stationary targets.

h. Stage of Training: Basic Armor Training (BAT)

i. Trainee Sophistication: Novice

j. User Acceptance or Attitude: Personal interviews were conducted by test directorate personnel with the 85 BAT students who used the TGMTS for training and the TGMTS instructors.

5. Discussion:

a. Major Findings:

(1) The TGMTS device, as measured by its training transfer, was found to be as effective as the M55 laser and cal .22 devices in providing initial tank gunner training to BAT students.

(2) There were no significant differences in two of the measures of performance (target effect and completion of crew duties) between TGMTS and non-TGMTS trained soldiers.

(3) There was a significant difference between precision engagement gunner times. TGMTS trained soldiers engaged targets an average of 1.5 seconds faster than non-TGMTS trained soldiers.

(4) There was a significant difference between the lay error of the subsequent round of conventional engagements. Non-TGMTS trained soldiers applied a change to their sights an average of .38 mil more accurately than TGMTS trained soldiers.

(5) No RAM indices were computed for TGMTS due to limited operation (60 hours).

(6) No major logistics supportability problems arose during the limited evaluation of TGMTS.

(7) The 18 hours of instructor training on TGMTS was found acceptable for conduct of BAT initial gunnery training.

(8) Installation and alignment of the TGMTS by the instructors met the established time criterion of 30 minutes.

(9) TGMTS controls and equipment were found to be easy to understand and use. No negative human engineering factors were encountered during the conduct of the test.

(10) TGMTS trained soldiers reportedly liked training on the device, especially the performance scoring and feedback which they felt aided them in correcting their gunnery mistakes.

(11) The TGMTS instructors were also positive about the realism and versatility of the device, but noted that the device has a tendency to lose alignment when moved to different sites.

b. Authors' Conclusions: The authors concluded that TGMTS was an effective, reliable, and maintainable device for training initial gunnery skills during BAT.

c. Limitations:

(1) TGMTS lacked a nighttime engagement capability.

(2) The TGMTS developed 13 malfunctions over the 60 test hours. Most of these problems were a result of overheating.

d. Considerations:

(1) Additional research (Ogle, 1983) demonstrated that performance on TGMTS predicted performance on TT VIII live-fire exercises. However, these results were based on a small sample size and must be replicated.

(2) Witmer suggested that TC-gunner performance can be accurately and reliably measured with computer-augmented TGMTS.

6. Related Work:

a. Ogle, J. T. (1983). 1st battalion 77 armor gunnery study. Unpublished manuscript.

b. Witmer, B. G. (1985). Using the Tank Gunnery and Missile Tracking System (TGMTS) for measuring tank gunnery performance (ARI Research Report 1417). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A170 895)

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32. Smith, E. P., & Graham, S. E. (1987). Validation of psychomotor and perceptual predictors of armor officer M1 gunnery performance (ARI Technical Report 766). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A191 333)

1. Topic Keywords: Armor; M1 Tank; Simulators; U-COFT; Gunnery; Psychomotor Predictors, Perceptual Predictors; Officer Selection.

2. Short Summary: This research examined the validity of a computerized and paper-and-pencil psychomotor and perceptual test battery for predicting M1 gunnery performance. Ninety-five Armor Officer Basic Course (AOBC) officers were administered the battery at the beginning of training and were tested on gunnery skills near course completion using the Unit-Conduct of Fire Trainer (U-COFT). Stepwise regression of U-COFT composite score resulted in a multiple R=.76, with seven variables in the model. Using discriminant analysis with this subset of variables, 94% of the sample were correctly classified into the top 95% and bottom 5% of the composite score distribution. Eighty percent (80%) were correctly assigned to the upper and lower thirds of the distribution. Although these findings require cross-validation, they provide useful information as the first step in developing an Armor officer pre-accession screen.

3. Performing Organization: U.S. Army Research Institute for the Behavioral and Social Sciences, Field Unit - Fort Knox, KY 40121-5620.

4. Approach: Experimental

a. Number of Groups: 1

b. Description of Groups: The subjects were 95 Armor second lieutenants attending AOBC for M1 training. The officers were taken from six AOBC classes over a seven month period, with each class ranging from eight to 24 officers.

c. Tests or Trials: Two separate testing sessions were used for administration of the predictors and criterion U-COFT tests. The subjects took the predictor battery during their first week of training; thus, six sessions of approximately three and one-half hours each. The subjects took the U-COFT test about two-three weeks before course completion. Since only three subjects could be tested at a time, there were 15-18 one hour sessions.

d. Number of Different Types of Measures Used: 2

e. Description of Measures/Ratings:

(1) Prediction Battery: The prediction battery was the Project A psychomotor and perceptual computer and paper-and-pencil test battery for predicting M1 gunnery performance for newly commissioned armor officers (Peterson, 1986). Half of the battery consisted of five paper-and-pencil tests of spatial visualization (rotation and scanning), spatial orientation, and figural reasoning (induction). The other half consisted of ten computerized tests, using a response pedestal specially designed for this test battery, measuring simple and choice reaction time (processing efficiency), short-term memory, psychomotor precision (2 tests), perceptual speed and accuracy (2 tests), two-hand coordination, number operations, and movement judgment. These tests provided a total of 32 different scores. Data analyses were performed using the scores individually and combined into six composites. The Nelson-Denny Reading Test, a measure of general verbal ability, was included as an additional predictor.

(2) U-COFT Criterion Test: The U-COFT test was designed to assess gunnery skills required for engaging targets with the main gun from the tank commander's (TC's) station. The test included a practice exercise, a tracking exercise, and three gunnery exercises approved by the Weapons Department, U.S. Army Armor School. The practice exercise (half of exercise 213110) contained five short-range moving targets which were fired at from a defensive position. The tracking exercise was a U-COFT "Acquisition and Manipulation" exercise used to assess smooth tracking ability. The exercise included five moving targets for which the TC had to lase, fire, and then track the target for about 30 seconds. The two performance measures were (a) percent time on target, measured from when the TC fired until the target disappeared, and (b) Root Mean Square (RMS) error from center of mass, calculated using the equation; RMS equals the square root of the azimuth and elevation errors squared. Because the TCs fired at different times, only the last 15 seconds of each track was tabulated to standardize the measure across targets and subjects. The three gunnery exercises consisted of ten target engagements each. The first exercise required the TC to fire at single long-range moving targets from a stationary tank. The

next exercise required the TC to fire at long-range stationary targets from a moving tank. The last exercise simulated failure of the stabilization system, including the auto lead system. This exercise required the TC to manually lead the short-range moving targets. The two dependent measures gathered from the three gunnery exercises were (a) number of hits, calculated as the umber of targets killed out of the ten presented for each of the three exercise (this was actually first round hits since only one round was fired at each target), and (b) mean opening times, calculated as the amount of time from when the target appears to when the first round is fired. For engagements in which no round was fired, an opening time of 24 seconds was entered--the maximum U-COFT opening time. In addition, a speed/accuracy score for the three exercises individually and over all combined was calculated by subtracting the standardized opening time score from the standardized hit score. An overall composite score was computed by combining the six standardized hits and opening times scores with the standardized RMS error score from the tracking exercise. Thus, the composite score equals the sum of the hits minus the sum of the opening times minus tracking RMS error.

f. Experimental Setting/Training Context: The research was conducted in an institutional setting using a hands-on testing approach. For the prediction battery, the subjects were randomly split into two groups. One group took the computer batter" first, the other took the paper-and-pencil tests first. e order of tasks within groups was standardized across subjects. All paper-and-pencil tests were timed. The subjects read the instructions and were given the opportunity to ask questions. The computerized tests were self-administered on Seequa Chameleon computers us. g the special response pedestal. All instructions were provided on the computer with a researcher available to answer questions. The Nelson-Denny Test was given during regular course time. For the U-COFT criterion test, U-COFT operation and testing was performed by seven qualified instructor/operators (I/Os). The I/Os provided detailed instructions on the use of the U-COFT before and during the practice exercises. No such instructions were permitted during the actual test exercises.

g. Statistical Methods: General descriptive statistics were calculated for predictor and criterion scores. Separate factor analyses were run on the criterion and predictor scores for data reduction purposes to create composite scores. Correlations were computed between the Nelson-Denny score and criterion score to compare the predictive validity of this score alone to that of the fully battery. Multiple regression analyses were performed on the criterion composite for sets of (1) individual predictor variables, (2) predictor composites based on the factor analysis, and (3) predictor composites based on Project A factor analysis data. The results were then used to select subsets of variables wi maximal relationship to the criterion nd th e variables el ed into discriminant analyses. F r ese analyses, subjects were divided into successful (top 5%) and unsuccessful (bottom 5%) groups based on their U-COFT composite scores. Additional regression analyses for the first and third exercises combined

and for the second exercise alone were performed to examine potential differences in predictive validity.

h. Use of Instructional Features: Standardized procedures were followed throughout both practice and testing periods to ensure that each TC had an equal opportunity to identify and engage targets (Graham, 1986). For example, the I/O was instructed to talk the TC onto a reference point before each engagement. Also, the reticle was positioned so that the target always emerged within the gunner's primary sight extension (GPSE) field of view.

5. Discussion:

a. Major Findings:

(1) Stepwise multiple regression of the U-COFT composite score on individual predictor variables resulted in a regression model containing seven variables from five tests with a multiple correlation coefficient (R) equal to .76. Thus, the regression model accounted for more than half (53%) of the variance in criterion scores.

(2) The Nelson-Denny score, as a measure of general ability, demonstrated little predictive validity (r=.20) for tank gunnery performance as measured in this research. Thus, it can explain only four percent (4%) of the criterion variance.

(3) Subsequent discriminant analysis with the reduced set of variables correctly classified 94% of the cases as successful (upper 95%) or unsuccessful (lower 5%), with most errors found for marginal cases; 80% were correctly assigned to the upper and lower thirds of the distribution.

b. Authors' Conclusions:

(1) The battery exhibits ample validity for predicting gunnery performance based on small sample size, whereas a measure of general verbal ability exhibits little validity.

(2) The findings provide useful information as the first step in developing an armor officer pre-accession screen using these or similar predictor measures.

c. Limitations: The research contained many variables of interest and only a small sample of subjects. This situation limits both the approach and the interpretation of the findings. Also, more analyses were done than typically would be acceptable.

d. Considerations:

(1) A major problem in attempting to predict armor gunnery performance is selection of the appropriate criterion. Ideally, predictor tests are validated against on-the-job performance; i.e., TT VIII scores. As an alternative to live-

fire testing, a U-COFT composite test score was used as the criterion performance measure.

(2) Although performance on similar U-COFT tests has been found to be reliable, test-retest reliability coefficients exceeding .80 (Graham, 1986), the reliability of this U-COFT test has not been determined.

6. Related Work:

a. General Electric (1985). Instructor's utilization handbook for the M1 Unit-Conduct of Fire Trainer (U-COFT) (Vol.1). Orlando, FL: Naval Training Equipment Center.

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

c. Peterson, N. G. (Ed.) (1986). Development and field test of the Trial Battery for Project A (ARI Technical Report 739). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A184 575)

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33. Smith, M. D., & Hagman, J. D. (1992). Predicting Table VIII tank gunnery performance from M-COFT hit rate and demographic variables (ARI Technical Report 955). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A254 580)

1. Topic Keywords: Armor; M1 Tank; Tank Gunnery; Tank Table VIII; Training Devices; M-COFT; U-COFT; Army National Guard.

2. Short Summary: This research examined the ability to predict Tank Table (TT) VIII performance from Mobile-Conduct of Fire Trainer (M-COFT) proficiency and crew demographics, and to develop cut scores for predicting TT VIII qualification. Tank commanders (TCs) and gunners in 24 Army National Guard (ARNG) M1 tank crews completed a M-COFT Test of Gunnery Proficiency (CTGP) developed by Hoffman and Witmer (1989), before firing TT VIII. The results revealed that (a) the CTGP Hit Rate correlated positively with TT VIII scores; (b) gunner's age, TC vision, and crew years of military service correlated with TT VIII; (c) TC's vision was related positively to TT VIII scores, whereas gunner's age was related negatively to both TT VIII scores and CTGP Hit Rate; (d) the relationship between crew years of military service and TT VIII was curvilinear (crews with intermediate years of service outperformed those with either a few or many years); (e) more than 60% of TT VIII score variance was accounted for when the three best predictor variables (gunner's age, crew years in Active Army, gunner's main gun experience) were combined in a

multiple regression algorithm; and (f) TT VIII performance can be predicted from a combination of M-COFT Hit Rate and other measures to support the viability of training strategies for ARNG armor units. Provided the results are replicable, M-COFT cut scores can be constructed to serve as guidelines; i.e., crews trained to specified levels of M-COFT proficiency can be expected (with known levels of probability) to qualify on TT VIII.

3. Performing Organization: CAE-Link Corporation, Link Training Services Division, 209 Madison Street, Alexandria, VA 22314.

4. Approach: Experimental

a. Number of Groups: 3

b. Description of Groups: Thirty six crews from four M1 ARNG companies within the same battalion were randomly assigned to one of three treatment groups.

(1) Group 1: The subjects were 10 M1 ARNG crews who completed the CTGP one month before AT and fired Table VIII.

(2) Group 2: The subjects were 14 M1 ARNG crews who completed the CTGP one day before AT and fired Table VIII.

(3) Group 3: The subjects were 12 M1 ARNG crews who were not administered the CTGP and fired Table VIII.

c. Tests or Trials: All TCs and gunners were tankers with a wide range of experience levels, had attained about the same position in the COFT matrix, and received two hours of M-COFT familiarization before the research started. Information on age, rank, length of military service, and years in current Military Occupational Specialty (MOS) were collected from each crew during their Table VIII debriefing. Following their annual training (AT), tank crews that were administered the CTGP were also administered a follow-up questionnaire on amount of TC and gunner experience and vision.

d. Number of Different Types of Measures Used: 3

e. Description of Measures/Ratings: The CTGP provided a composite gunnery performance measure, a "test wide" M-COFT performance measure that is weighted for the number of targets in each of the 22 contributing engagements. This composite measure of gunnery proficiency is called Hit Rate, which Hoffman and Witmer (1989) defined as: Hit Rate (hits/time) = Hit Proportion (hits/rounds) X Fire Rate (rounds/time). "Hit rate, adjusted for hits on friendly targets, is the recommended metric for assessment of overall crew proficiency. Hit rate is calculated for each engagement from information on M-COFT printouts on rounds fired, hits, and time. Overall hit rate is calculated from the weighted averages for firing rate and hit probability, where engagement firing rates and hit probabilities are weighted by the number of targets in the engagement." (Hoffman and Witmer,

1989; p 28). The M-COFT software (General Electric, 1985) also provided numerous subsidiary measures which were categorized by (1) target acquisition (four measures), (2) fire rate (ten measures), (3) accuracy of fire (seven measures), and (4) systems management (three measures). The TT VIII provided raw scores for individual engagements, (which are based on engagement speed, firing accuracy, and threat capability) minus penalty points (crew cuts deducted from each engagement raw score). Scores were summed for day, night, and total (day and night) performance.

f. Experimental Setting/Training Context: The research was conducted in an institutional and field setting, WITH M-COFT, TT VIII, and demographic data obtained from TCs and gunners of 24 M1 tank crews (Groups 1 and 2). Except for M-COFT and demographic measures, data were also collected from TCs and gunners of 12 additional crews from the same battalion to assess the impact of CTGP administration (Group 3). The CTGP consisted of four M-COFT matrix exercises selected to correspond to conditions that occur in TT VIII (Hoffman and Witmer, 1989). The CTGP included a standardized set of administration procedures with no feedback or coaching allowed during testing. The instructor/operators (I/Os) for the CTGP were two master gunners trained to follow the test administration procedures which took approximately 1 hour per crew. Table VIII scores were collected at the first operation of a new, computer-automated range where all hit/miss decisions were assessed electronically. Each crew fired six day and four night target engagements, selected from among the 14 engagements described in FM 17-12-1 (Department of the Army, 1988).

g. Statistical Methods: Data were analyzed using the Statistical Package for the Social Sciences (SPSS). Descriptive statistics, Pearson product-moment correlation coefficients (r), analyses of variance (ANOVA) techniques, and multiple stepwise regression analyses were conducted to assess the relationships between variables and COFT or Table VIII performance measures.

h. Trainee Sophistication: Experienced TCs and gunners with a wide range of experience levels.

5. Discussion:

a. Major Findings:

(1) The mean TT VIII score was 356, with a standard deviation of 184. Only one of the 24 tank crews in Groups 1 and 2 qualified, with scores ranging from 59 to 703. The predominant reason for the low scores was the crews' inability to acquire targets in time to fire a round.

(2) M-COFT Hit Rate, a composite measure of tank gunnery performance from the CTGP, correlated significantly with TT VIII scores. Hit Rate was found superior to specific performance measures in predicting TT VIII performance.

(3) Generally, the greater the number of M-COFT training exercises used to calculate the M-COFT Hit Rate, the stronger its correlation with TT VIII.

(4) Relationships between M-COFT Hit Rate and TT VIII were robust with either one-day or 30-day intervals between M-COFT testing and TT VIII.

(5) The strong multiple correlation between combination of M-COFT Hit Rate, TC vision, and crew years of military service permitted development of cut scores, or specific M-COFT Hit Rate objectives. If the prediction model proves valid, M-COFT scores can be used to predict the probability of TT VIII qualification.

b. Authors' Conclusions:

(1) The research findings are not suitable bases for revising current training policies until the findings can be replicated.

(2) The results indicated that TT VIII performance can be reliably predicted from both M-COFT Hit Rate and demographic variables.

(3) If the research findings are replicable and the suggested model is valid, then the M-COFT can be used to identify tank crews with both the highest probability of qualifying on TT VIII, as well as those tank crews most urgently in need of remedial training.

d. Limitations:

(1) Two hours of M-COFT familiarization and one hour of CTGP administration may be insufficient to propose training guidelines for the device.

(2) The computer-mediated firing range with electronic scoring system was used for the first time to collect TT VIII data and may have influenced both the mean level and internal consistency of the scores. As reported, some TT VIII scores were low because targets were never identified by the crews.

(3) The prediction model was based on a small number of tank crews (N=24) and on first-run TT scores which were affected more by the crews' inability to acquire the target than obtaining a target hit.

(4) Differential attrition from Group 1 was reported to have occurred due to TC/gunner changes during the 30 day interval between administration of the CTGP and TT VIII. However, all data analysis were based on 24 intact crews; i.e., tank crews having no TC or gunner changes.

(5) Given the large number of correlations between M-COFT measures and TT VIII total score (27), a few significant

correlations are expected with $p = .05$ if they are independent. Because the correlations are dependent, the expected number is unknown and several of those shown as significant are probably Type I errors.

e. Considerations: The TT VIII scores are heavily weighted by the crews' inability to acquire the target--a time requirement that must be met in order to receive a points score on any of the ten engagements. Until the findings are replicated using a larger sample size, the model suggested by the authors cannot be considered valid to either identify crews with both the highest probability of qualifying on TT VIII or those most urgently in need of remedial training.

6. Related Work:

a. Department of the Army (1988). Tank combat tables M1 (Field Manual 17-12-1). Washington, DC: Author.

b. DuBois, 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, Bowling Green, KY.

c. General Electric (1985). Instructor's utilization handbook for the M1 Unit-Conduct of Fire Trainer (U-COFT) (Vol.1). Orlando, FL: Naval Training Equipment Center.

d. 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)

e. Hoffman, R. G., & Witmer, B. G. (1989). Development of a Unit-Conduct of Fire Trainer (U-COFT) test of M1 gunnery proficiency (ARI Technical Report 859). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A219 045)

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34. Smith, M. D., & Hagman, J. D. (1992). Interdevice transfer of training between the Guard Unit Armory Device, Full-Crew Interactive Simulation Trainer-Armor (GUARDFIST I) and the Mobile Conduct-of-Fire Trainer (M-COFT) (ARI Research Report 1635). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

1. Topic Keywords: Armor; Armor Training; Tank Gunnery; Table VIII; Reserve Component; Training Devices; M-COFT; GUARDFIST I.

2. Short Summary: This research examined interdevice transfer between the Mobile-Conduct of Fire Trainer (M-COFT) and the Guard

Unit Armory Device, Full-Crew Interactive Simulation Trainer - Armor (GUARDFIST I), and the relationship between tank gunnery performance on the two devices. Thirty-four M1 Army National Guard (ARNG) tank crews (tank commander (TC)/gunner pairs) were assigned to two treatment groups. Group 1 was pretested and trained on M-COFT and posttested on GUARDFIST I. Group 2 was pretested and trained on GUARDFIST-I and posttested on M-COFT. The results revealed that (a) M-COFT training significantly improved the speed and firing accuracy of GUARDFIST I posttest scores, whereas GUARDFIST I training improved only the speed of M-COFT posttest scores; and (b) performance on each device was significantly, but moderately, related with higher correlations occurring between more temporally contiguous measures: pretest scores with training measures, and training measures with device posttest scores. The findings suggest that the two devices can be used interchangeably to improve the speed of tank gunnery engagements, whereas M-COFT should precede GUARDFIST I usage to improve firing accuracy. Estimated times for completion of training matrix exercises on each device were provided.

3. Performing Organization: CAE-Link Corporation, Link Training Services Division, 5111 Leesburg Pike, Suite 300, Falls Church, VA 22314.

4. Approach: Experimental

a. Number of Groups: 2

b. Description of Groups: The subjects were 34 tank crews (TC/gunner pairs) from an M1 ARNG battalion who were randomly assigned by company to two treatment groups. All TCs and gunners were experienced, with about two hours of prior experience on both M-COFT and GUARDFIST I.

(a) Group 1: The subjects were 19 crews who were given an M-COFT pretest, trained on M-COFT using a modified training matrix that included specific exercises related to Tank Table (TT) VIII engagement conditions, and posttested on GUARDFIST I.

(b) Group 2: The subjects were 15 crews who were given a GUARDFIST I pretest, trained on GUARDFIST I using a modified training matrix that included specific exercises related to TT VIII engagement conditions, and posttested on M-COFT.

c. Tests or Trials:

(1) M-COFT Test: The M-COFT test consisted of two exercises (346311 and 346111) selected from the current U-COFT TC/gunner training matrix, designed to cover a variety of engagement conditions practiced during GUARDFIST I training. The testing conditions included day and night engagements requiring the use of the Gunner's Primary Sight (GPS), Gunner's Auxiliary Sight (GAS), and Thermal Imaging Sight (TIS); full-crew and three-man conditions; nuclear, biological, and chemical (NBC) conditions; and both a stationary and moving tank firing at a

total of 20 stationary and moving targets ranging from 920-2080 meters with most (90%) occurring at distances between 1530-2080 meters. No feedback or coaching was permitted during testing.

(2) GUARDFIST I Test: The GUARDFIST I test was designed to include a variety of engagement conditions practiced during M-COFT training. One task was included from each of five group/exercise combination taken from the current GUARDFIST I training and evaluation matrix (Department of the Army, 1990). Across tasks, testing conditions were varied to include day and night engagements requiring the use of the GPS, GAS, and TIS; full-crew and three-man (gunner out) conditions; NBC conditions; and both a stationary and moving tank firing at a total of nine stationary and moving targets ranging from 800-2000 meters. No feedback or coaching was permitted during test administration.

d. Number of Different Types of Measures Used: 2

e. Description of Measures/Ratings:

(1) Gunnery Measures: Both the M-COFT and GUARDFIST I tests were scored according to the criteria developed by Hoffman and Witmer (1989) to produce Fire Rate, Hit Rate, and Hit Proportion scores. Hit Rate is an aggregate measure of gunnery proficiency weighted for number of targets in each engagement. Hit Rate (hits/time) is defined as hit proportion (hits/rounds) multiplied by fire rate (rounds/time). The other two measures were the number of device-passes (GOs) on the GUARDFIST I test, and the proportion of targets fired on during the M-COFT test. Proportion of targets fired on was defined as number of different targets fired on divided by total number of available targets.

(2) Training Measures: Five measures were obtained: (a) matrix advancement (for the modified M-COFT training matrix, this was number of successfully completed exercises; for the GUARDFIST I matrix, advancement was determined by combining all available training and evaluation exercises in the unmodified matrix and counting consecutively to the point of maximum advancement); (b) attempted exercises (the sum of all exercises attempted--GOs plus NO GOs; (d) trial efficiency (completed exercises divided by total number of attempted exercises); (e) training time (total combined training time in minutes across all sessions); and (f) time efficiency (completed exercises divided by total training time in minutes).

f. Experimental Setting/Training Context: The research was conducted in an institutional setting using a hands-on approach. All training and testing was conducted by unit GUARDFIST I and M-COFT instructor/operators (I/Os), under researcher supervision. A training exercise with M-COFT and task with GUARDFIST I involve different situations. An M-COFT exercise typically comprises from four to five times as many targets as a GUARDFIST I task. Each crew was scheduled for one training session at their local armory during three consecutive inactive duty training weekends. The amount of training time each crew received during each

session was allowed to vary so that amount of training and extent of matrix advancement could be used as variables to predict subsequent posttest scores on the alternate device. All crews were informed prior to training that both speed and firing accuracy would be evaluated. Feedback was not allowed during testing, but was provided during training to promote learning. Crews were encouraged to advance as far as possible into the modified training matrix, but could proceed to the next training unit only when they received a "GO" from the training device. A "NO GO" resulted in a repeat of the same exercise, and crews could repeat an exercise as often as needed to achieve a "GO." Device training began immediately following the pretests, with posttests given from one to three months after training completion. Maneuver training occurred during device training and posttesting. Demographic data were collected during the pretests on TCs' and gunners' age, amount of gunnery experience (13 dimensions), rank, and visual acuity. Seven TCs and five gunners did not return their questionnaires.

g. Statistical Methods: Descriptive statistics, Pearson product-moment correlations, and analyses of variance (ANOVA) and covariance (ANCOVA) were calculated to assess the relationships between variables and M-COFT or GUARDFIST I measures.

h. Trainee Sophistication: Experienced TCs and gunners.

5. Discussion:

a. Major Findings:

(1) M-COFT training transferred to speed of engagement (Fire Rate) and accuracy (Hit Rate) on GUARDFIST I.

(2) For crews that received sufficient GUARDFIST I training on offensive engagements, GUARDFIST I training transferred to M-COFT, but only for speed of engagement (Fire Rate) and not accuracy (Hit Rate).

(3) GUARDFIST I posttest scores for Group 1 were significantly higher than GUARDFIST I pretest scores for Group 2.

(4) GUARDFIST I Fire Rate, Hit Rate, and number of offensive engagements receiving a "GO" differed significantly, while GUARDFIST I Hit Proportion scores approached significance.

(5) Despite random assignment procedures, Group 1 tank crews were superior to crews in Group 2 prior to any testing or training, enabling them to score as high on M-COFT prior to any training as Group 2 scored after GUARDFIST I training.

(6) For Group 1, advancement into the M-COFT training matrix was the best predictor of subsequent GUARDFIST I posttest scores. In turn, advancement into the M-COFT training matrix was predictable from M-COFT pretest scores. Greater advancement was obtained by crews that achieved high pretest Fire Rate scores.

(7) For Group 2, Trial Efficiency (measure of crews' speed of advancement through the GUARDFIST I training matrix) was significantly related to a host of subsequent M-COFT test scores.

(8) The pattern that emerged for both training groups was that high pretest scores predicted training success on the same device. Training success, in turn, predicted subsequent posttest scores on the alternative device.

(9) Device scores were significantly, but moderately, intercorrelated. Hit Rate from the two devices correlated significantly and GUARDFIST I Fire Rate was significantly related to both M-COFT Hit Rate and Hit Proportion.

(10) The results supported the interim training strategy recommendation of 16 GUARDFIST I training hours (Morrison, Campshure, & Doyle, 1990), but the 26 hours of M-COFT training permitted only 54 of 510 exercises (390 European environment and 120 Desert environment) to be completed.

b. Authors' Conclusions:

(1) The positive transfer and correlational findings of the research suggest that M-COFT and GUARDFIST I can be used interchangeably to improve the speed of device-based tank gunnery engagements, whereas M-COFT should be used for improving their accuracy.

(2) If both devices are used for training, the most effective/efficient device usage sequence would be M-COFT first, then GUARDFIST I, at least for TT VIII related engagement conditions found in common in the device training matrices.

(3) The training time estimates can be used to support efficient scheduling of gunnery training on the two devices.

(4) Additional research is recommended to identify the amount of transfer to live-fire performance that can be expected from training on each device both individually or in combination.

c. Limitations:

(1) Despite random assignment procedures, Group 1 tank crews were superior to crews in Group 2 prior to any testing or training, enabling them to score as high on M-COFT prior to any training as Group 2 scored after GUARDFIST I training.

(2) Data on confounding variables (besides training) that might have had a differential impact on the two companies during the three month interval were not analyzed and may have affected the observed or lack of differences in device scores.

(3) GUARDFIST I crews trained longer than M-COFT crews, and it was possible for less proficient crews to receive longer training sessions.

d. Considerations:

(1) Longer M-COFT and GUARDFIST I tests are considered necessary, since most of the relationships found between overall device scores were traceable to only one of two M-COFT exercises.

(2) Larger sample sizes and longer training intervals than those reported are necessary to determine the possibility of GUARDFIST I to M-COFT transfer in regard to accuracy.

6. Related Work:

a. Department of the Army (1988). Tank combat tables M1 (Field Manual 17-12-1, C3). Washington, DC: Author.

b. Department of the Army (1990). Guard Unit Armory Device for Full-Crew Interactive Simulation Training-Armor (GUARDFIST I). Washington, DC: Author.

c. General Electric (1985). Instructor's utilization handbook for the M1 Unit-Conduct of Fire Trainer (U-COFT) (Vol.1). Orlando, FL: Naval Training Equipment Center.

d. Hoffman, R. G., & Witmer, B. G. (1989). Development of a Unit-Conduct of Fire Trainer (U-COFT) test of M1 gunnery proficiency (ARI Technical Report 859). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A219 045)

e. Morrison, J. E., Campshure, D. A., & Doyle, E. L. (1990). A device/aid-based strategy for training M1 tank gunnery in the Army National Guard (ARI Research Report 1587). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A240 752)

f. Smith, M. D., & Hagman, J. D. (1992). Predicting Table VIII tank gunnery performance from M-COFT hit rate and demographic variables (ARI Technical Report 955). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A254 580)

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35. Turnage, J. J., & Bliss, J. P. (1990). An analysis of skill transfer for tank gunnery performance using TOPGUN, VIGS, and I-COFT trainers (ARI Technical Report 916). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A231 156).

1. Topic Keywords: Armor; M1 Tank; Training Devices; TOPGUN; VIGS; U-COFT; I-COFT; Tank Gunnery Performance; Skill Transfer; Predictor Tests; APTS; VISTECH 6500; ASVAB.

2. Short Summary: This research examined skills transfer for

gunnery performance using the Videodisk Gunnery Simulator (VIGS), the Institutional-Conduct of Fire Trainer (I-COFT), and TOPGUN. Sixty students subjects were randomly assigned to a VIGS-First, TOPGUN-First, or Control group. Subjects in the two experimental groups were given four hours of training (two trials per day for two days) on TOPGUN or VIGS and then switched to the alternate device for four hours of training. All subjects were then tested on the I-COFT, with subjects in the experimental groups also given two device opinion questionnaires to complete. The results revealed that (a) device performance improved at equal rates during both TOPGUN and VIGS training; (b) significant transfer occurred between most TOPGUN and VIGS performances, with no superiority for either device; (c) TOPGUN and VIGS training transferred to I-COFT (except for speed measures), (d) there were no differences between the TOPGUN-VIGS or VIGS-TOPGUN sequence of training; and (e) highly reliable predictor tests were the best indicators of gunnery performance on the three devices, despite generally low multiple correlations.

3. Performing Organization: University of Central Florida, Institute for Simulation and Training (IST), P.O. Box 25000, Orlando, FL 32816.

4. Type of Article: Experimental

a. Number of Groups: 3

b. Description of Groups: The subjects were 60 male undergraduate and graduate students attending the University of Central Florida (UCF) who volunteered to participate in the research for $5.00 per hour. During the first week of each subject's three week experimentation period, subjects completed a battery of predictor tests and a single test for color-blindness. Testing followed standardized instructions and administrative procedures, took about four hours, and was completed in the following order: (1) Ishihara Color-blindness test, (2) VISTECH 6500 contrast sensitivity test, (3) Automated Performance Test System (APTS) [1st replication], (4) Armed Services Vocational Aptitude Battery (ASVAB), (5) APTS (2nd replication), (6) Work and Family Orientation (WOFO) questionnaire, (7) APTS (3rd replication), and (8) VISTECH (2nd replication). Third and fourth replications of VISTECH 6500 took place in subsequent sessions.

c. Tests or Trials:

(1) Subjects in TOPGUN-First Group: These 20 subjects received TOPGUN familiarization followed by four hours (two two-hour trials per day for two days) of TOPGUN training. They then received VIGS familiarization followed by four hours (two two-hour trials per day for two days) of VIGS training. On training compl ion, they received I-COFT familiarization and testing (two and one-half hours), then completed opinion questionnaires about the TOPGUN and VIGS.

(2) Subjects in VIGS-First Group: Same as above, except the subjects were given VIGS training first.

(3) Subjects in Control Group: These 20 subjects were given only I-COFT familiarization and testing.

d. Number of Different Types of Measures Used: 16

e. Description of Measures/Ratings: The 4 predictor tests were: (1) APTS consisting of seven performance tests (Tapping, Force-Choice Visual Reaction Time, Code Substitution Test, Grammatical Reasoning, Pattern Comparison Test, Manikin Test, and Mathematical Processing), (2) WOFO questionnaire, (3) VISTECH 6500, and (4) Armed Services Vocational Aptitude Battery (ASVAB) consisting of five major areas (General Science, Coding Speed, Automotive and Shop Information, Mechanical Comprehension, and Electrical Information). The 6 performance measures for TOPGUN and VIGS were: (1) elevation and azimuth aiming errors (in mils) from the target center of mass, (2) time to fire (time from presentation of the target to firing the first round), (3) time to kill, (4) first round hit percentage (first round hits divided by total number of first rounds fired), (5) computer composite score from TOPGUN, and (6) computer composite score from VIGS. The 6 performance measures for I-COFT were (1) time to fire, (2) time to kill, (3) number of rounds, (4) number of hits (from which hit percentage was calculated), (5) computer composite score for Target Acquisition, and (6) computer composite score for Reticle Aim.

Note. The time to fire, time to kill, and aiming error measures for TOPGUN were based on first round data. Also, the hit percentage did not account for engagements in which no rounds were fired. The computer composite score for TOPGUN and VIGS were different; TOPGUN included second round data. The two I-COFT computer composite scores were calculated differently than those obtained from either the TOPGUN or VIGS.

f. Experimental Setting/Training Context: The research was conducted in an institutional setting using a hands-on training and testing approach. Device familiarization training included information about the device, how to use the gunner's control handles and switches, and six practice engagements of each type of target to be encountered. TOPGUN training consisted of two 36-target trials per day, each of which took about 20 minutes to complete. The engagements represented a cross-section of target arrays and device settings using the Gunner's Primary Sight (GPS), then Thermal Imaging Sight (TIS) and Gunner's Auxiliary Sight (GAS). Target arrays were sequenced within each sight mode so that single stationary targets appeared followed by single moving targets and then multiple stationary and moving targets. The total number of TOPGUN engagements was 144. VIGS training consisted of two 41-target trials per day, each of which took about 50 minutes to complete. The VIGS engagements also presented a cross-section of conditions and device settings. The target array sequencing was identical to that of TOPGUN, except

for the number of engagements per target array. The total number of VIGS engagements was 164. Three trained Instructor/Operators (I/Os) gave the I-COFT test using standard test procedures (Hoffman & Witmer, 1989). After device familiarization, subjects performed 6 I-COFT exercises (10 engagements per exercise) given in order (312110, 313110, 322610, 323210, 332110, 333110). The engagements were selected to closely match those on TOPGUN and VIGS. All coaxial machine gun (COAX) engagements were deleted from the analyses. In addition to immediate feedback provided by the devices, the experimenter also corrected performance during trials, gave verbal instruction and feedback following trials to promote learning, and provided subjects a verbal critique of errors per trial.

g. Statistical Methods: To determine trial effects on VIGS and TOPGUN, group means and standard deviations were calculated for each of the criterion measures by trial and experimental group and for all the repeated measures (the APTS series, VISTECH charts, TOPGUN and VIGS scores). These data were subsequently used to measure the extent of stabilization (Jones, 1980; Jones, Kennedy, & Bittner, 1981) and the slope of the learning curve. To determine device stability and reliability, reliabilities for TOPGUN and VIGS criterion measures were estimated by calculating the average intertrial correlation across the four trials for each device. To determine relationships among device measures, intercorrelations for the combined VIGS-first and TOPGUN-first groups were obtained by calculating the average score across engagements for each subject and then correlating the averages. To determine whether performances measured on one device related to performance on the other devices, cross-correlations were calculated for averaged measures of gunnery performance on each device. To determine whether gunnery performance improved during TOPGUN and VIGS training and if TOPGUN performance transferred to VIGS performance, and vice versa, an analysis of variance (ANOVA) was applied to the performance criteria common to both TOPGUN and VIGS. To determine if TOPGUN and VIGS training transferred to I-COFT performance and which training sequence demonstrated better transfer to I-COFT, ANOVA summaries and contrasts were used to compare all groups on their I-COFT performances. To determine if aptitude, ability, motivational, demographic, and experience measures predicted TOPGUN and VIGS performance, all predictors (22) were correlated with all of the criterion variables for each experimental group and combined. The Spearman (1904) correction for attenuation formula was used to correct for the inherent unreliability of variables. Multiple stepwise regressions were performed using all the predictors as independent variables and each criterion as dependent variables.

h. Trainee Sophistication: Novice

i. User Acceptance or Attitude: After each training group completed their I-COFT test, a questionnaire was given to collect user opinions on the TOPGUN and VIGS gunnery trainers. A 5-point scale was used with "3" being a "neither agree nor disagree" rating. Subject comments were also collected and summarized.

5. Discussion:

a. Major Findings:

(1) The trial effects on TOPGUN and VIGS revealed that VIGS had (a) longer time to fire and kill scores, (b) greater azimuth error scores, and (c) lower composite scores. For both groups, skill acquisition proceeded slowly but consistently, and performance had not stabilized by the last training trial.

(2) Stability and reliability of the devices revealed that (a) VIGS performances were consistently less stable and reliable across trials for all measures, (b) TOPGUN performance on five of the same measures indicated significant stability and reliability, and (c) none of the reliabilities calculated for the I-COFT criterion measures across exercises was significant (because no repeated testing could be accomplished, the analysis tended to grossly underestimated the true I-COFT reliabilities).

(3) Relationships among device measures showed that speed, due to the artifact of using only first round data for analysis, were highly correlated. For all, composite scores were related significantly to the hit percentage scores. Speed scores were highly related to composite scores for TOPGUN and VIGS and to Reticle Aim grades (all in a negative direction) for I-COFT; thus illustrating the speed vs. accuracy tradeoff (i.e., greater speed relates to greater inaccuracy in target acquisition).

(4) No significant correlations were found between the TOPGUN and VIGS measures. TOPGUN speed measures correlated significantly with similar I-COFT measures, but not for accuracy. Performance scores (target acquisition, reticle aim) and time to fire correlated significantly between VIGS and I-COFT, suggesting the two devices may be measuring a common ability. The extremely low correlation between hit percentage on VIGS and I-COFT, the best accuracy measure available on I-COFT, suggested no relationship between accuracy on the two devices.

(5) Training transfer between TOPGUN and VIGS was found significant on both speed measures and two accuracy measures (hit percentage, performance score). In all cases, the group which received prior training on the alternate device performed better. Average aiming errors were too erratic to produce interpretable results. No interactions were found statistically significant.

(6) Training transfer from VIGS and TOPGUN to I-COFT found no significant difference on the speed measures. However, the experimental groups significantly outperformed the control group on all other measures. When trial four data were used to determine transfer, the TOPGUN-first group was found superior in terms of the I-COFT composite, demonstrating faster performance scores for both speed measures and higher hit percentage.

(7) The stability and reliability of gunnery predictors found that all APTS tests were highly reliable, with all except

Math Processing and Four-Choice Reaction Time having estimated reliability correlations greater than .707, the value at which 50% of the variance is explained. VISTECH measures of contrast acuity achieved very high reliabilities, particularly the higher spatial frequencies. Four ASVAB tests (general science, auto and shop, mechanical comprehension, electronics information) were positively correlated, but were negatively correlated with coding speed. All the WOFO achievement motivation scores were highly correlated. Inter-test correlations within the four predictor sets were moderately high, and cross-task correlations among predictor scores indicated the predictor sets were relatively independent. Correlations and regressions of predictors with criterion scores indicated that (a) contrast sensitivity, coding speed, and knowledge of specific mechanical principles predicted TOPGUN performance, (b) code substitution predicted VIGS performance, and (c) response speed and knowledge of mechanical principles predicted I-COFT performance.

(8) Subjects indicated that they enjoyed training on both devices and thought the devices helped them to improve or learn tank gunnery skills. Subjects experienced more difficulty with VIGS than TOPGUN, but were fairly evenly divided over which device they would use if given a choice. Also, there was equally strong support for the effectiveness of prior TOPGUN and VIGS training in helping performance on the I-COFT.

b. Authors' Conclusions:

(1) Gunnery performance improved at equal rates during TOPGUN and VIGS training.

(2) Significant transfer occurred between most TOPGUN and VIGS performances with no superiority between devices.

(3) TOPGUN and VIGS training transferred to I-COFT, except for speed measures.

(4) There was no apparent difference between the TOPGUN-VIGS or VIGS-TOPGUN sequences of training.

(5) Highly reliable predictor tests (code substitution and reaction time tests from APTS; contrast sensitivity test from VISTECH; and "mechanical comprehension" and "auto and shop" from ASVAB) were the best indicators of performance on the devices.

c. Limitations: Because of unreliable raw scores, such as elevation and azimuth aiming errors, composite performance scores were used which differed across the training devices; i.e., the scores were calculated differently. Although composite measures may possess greater validity, their reliabilities are difficult to measure because they combine many different elemental skills which may themselves be uncorrelated with each other. By being based on such diverse elements, their use permits potential interpretation problems regarding the transfer of specific skills between devices.

d. Considerations: The predictive validities of ability and nonability tests as well as the devices themselves are attenuated due to criterion unreliability. Both TOPGUN and VIGS performance measures have questionable reliabilities. This would have to be presumed for I-COFT because of subject inexperience, the relative complexity of the device and target engagements, and the use of only one test trial. Also, repeated testing serves to increase statistical power, often by increasing reliability.

6. Related Work:

a. Hoffman, R. G., & Witmer, B. G. (1989). Development of a Unit-Conduct of Fire Trainer (U-COFT) test of M1 gunnery proficiency (ARI Technical Report 783). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A219 045)

b. Jones, M. B. (1980). Stabilization and task definition in a performance test battery (Final Report, Contract N00203-79-5089, Monograph No. NBDL-M001). New Orleans, LA: Naval Biodynamics Laboratory. (ADA 099987)

c. Jones, M. B., Kennedy, R. S., & Bittner Jr, A. C. (1981). A video game for performance testing. American Journal of Psychology, 94, pp 143-152.

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36. Wheaton, G. R., Rose, A. M., Fingerman, P. W., Leonard, R. L., & Boycan, G. G. (1976). Evaluation of three burst-on-target trainers (ARI Research Memorandum 76-18). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A076 820)

1. Topic Keywords: Armor; M60A1; Training Devices; Wiley; Green Hornet; Training Transfer; Training Effectiveness; Fidelity.

2. Short Summary: This research evaluated the training device effectiveness of three Burst-on-Target (BOT) trainers (17-4 or "Green Hornet"; 17-4M (modified version of "Green Hornet"); and 17-B4 or "Wiley"). Three groups of 18 M60A1 armor trainees were trained to a criterion (90% of targets hit with two rounds or less). A fourth group of 18 trainees served as the control group which trained for a specified number of trials, using the 3A102B laser device, rather than to a criterion. After training, all groups performed a transfer test (80 trials with the M3A102B). Results indicated that the devices were almost equal in training effectiveness, but differed in complexity, physical fidelity, and handling. It was suggested that differences between training instructors lead to differing levels of performance.

3. Performing Organization: American Institutes for Research (AIR), 1055 Thomas Jefferson Street, NW, Washington, DC 20007; U.S. Army Research Institute for the Behavioral and Social Sciences, Field Unit - Fort Knox, Fort Knox, KY 40121-5620.

4. Approach: Experimental

a. Number of Groups: 4

b. Description of Groups: The subjects were 80 M60A1 (MOS 11E10) armor trainees. To create four equivalent groups (three groups assigned to one of three devices and a control group), subjects were matched according to their Army status, prior service, General Technical score, educational level, and end-of-block score. After attrition, each group contained 18 subjects.

(1) Group 1: Trained with the 17-4 (Green Hornet).

(2) Group 2: Trained with the 17-4M (modified version of Green Hornet).

(3) Group 3: Trained with the 17-B4 (Wiley).

(4) Group 4: Trained with M60A1/3A102B laser device (control group).

c. Tests or Trials: The acquisition phase involved training armor trainees to a specified firing proficiency criterion; 90% of targets hit with two rounds or less. A post-test training transfer task was developed as a performance criterion. This test involved firing two 40-trial sessions (one morning and one afternoon) using a 3A102B laser device mounted on an M60A1 tank.

d. Number of Different Types of Measures Used: 3

e. Description of Measures/Ratings: The three performance measures were: (1) accuracy (percent of target hits), (2) speed (time between bursts); and (3) trials to criterion (for training trials only).

f. Experimental Setting/Training Context: This research was conducted in an institutional and field setting using a hands-on training and testing approach. Various counterbalancing procedures were used to control potential sources of error related to (1) differences in instructors; (2) differences between the devices used within each group; (3) time of day for the transfer task; (4) different tank commanders during the criterion task; and (5) differences among tanks in the criterion task. A questionnaire was given to all trainees after training to ascertain their device preference. A similar questionnaire was given to instructors after the transfer task.

g. Statistical Methods: Descriptive statistics were computed for each performance measures. Analysis of variance (ANOVA) procedures and Scheffe tests were used to examine differences between groups in terms of speed and accuracy.

h. Stage of Training: Trainees.

5. Discussion:

a. Major Findings:

(1) Results from the acquisition phase indicated that trainees using the "Green Hornet" (17-4) reached the 90% proficiency criterion faster than those using the modified version (17-4M) or the "Wiley" (17-B4).

(2) All four groups' gunnery proficiency increased with practice. However, the initial percentage of hits by the "Wiley" group was below that of the two other device groups. Also, the "Wiley" group took longer times between shots.

(3) Results from the transfer phase indicated no significant differences between groups with respect to accuracy.

(4) Each device led to positive transfer of training in terms of speed in applying BOT.

(5) The group using the "Green Hornet" and its modified version reduced their time between rounds as a function of practice, whereas the "Wiley" group did not.

(6) After the transfer phase, the training instructors rated the modified version of the "Green Hornet" to be better than the other two devices. However, acceptance data from trainees revealed no difference in device preference.

b. Authors' Conclusions: The authors concluded the three devices were equally effective for training procedures involved in firing the M60A1 main gun. Also, a possible training strategy would be to use all three devices in a sequential progression.

c. Limitations and Considerations:

(1) The authors discussed differences in the complexity, physical fidelity, and handling of the three devices. These variations, along with differences between training instructors, were hypothesized to lead to differing levels of performance. Also, no discussion was provided for the difference between instructor and trainee device preferences.

6. Related Work:

a. Rose, A. M., Wheaton, G. R., Leonard, R. L., Fingerman, P. W., & Boycan, G. G. (1976). Evaluation of two tank gunnery trainers (ARI Research Memorandum 76-19). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A082 954)

b. Wheaton, G. R., Fingerman, P. W., Rose, A. M., & Leonard, R. L. Evaluation of the effectiveness of training devices: Elaboration and application of the predictive model (ARI Research Memorandum 76-16). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A076 815)

c. Wheaton, G. R., Rose, A. M., Fingerman, P. W., Korotkin, A. L. & Holding, D. H. (1976). Evaluation of the effectiveness of training devices: Literature review and preliminary model (ARI Research Memorandum 76-6). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A076 809)

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37. Witmer, B. G. (1985). Using the tank gunnery and missile tracking system (TGMTS) for measuring tank gunnery performance (ARI Research Report 1417). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A170 895)

1. Topic Keywords: Armor; M60A3 Tank; Tank Gunnery Training; Training Devices; TGMTS; Performance Testing; Measurement.

2. Short Summary: This research assessed the tank gunnery performance of 18 M60A3 tank commander (TC)-gunner pairs using the Tank Gunnery and Missile Tracking System (TGMTS). The test results indicated that (a) TC-gunner performance can be reliably assessed using the computer-augmented TGMTS; (b) higher hit probabilities and faster engagement times were achieved by more experienced gunners; and (c) target hit probabilities decreased as range-to-target distance increased. Potential areas for future device utilization were: personnel assignment, diagnostic testing, evaluation of tank gunnery training programs, and as a substitute for dry or live-fire.

3. Performing Organization: U.S. Army Research Institute for the Behavioral and Social Sciences, Field Unit - Fort Knox, KY 40121-5620.

4. Approach: Analytical

a. Number of Groups: 1

b. Description of Group: The subjects were 18 M60A3 TC-gunner pairs from two Armor units at Fort Knox. Nine of the TC-gunner pairs were selected from the primary support unit and the remaining nine pairs were selected from an operational unit.

c. Tests or Trials: The TGMTS uses a rear-projected movie that depicts armor targets moving across realistic terrain. Each TC-gunner pair engaged 27 targets, nine per film. The order of presentation was counterbalanced so that each of three films was shown an equal number of occasions first, second, and third.

d. Number of Different Types of Measures Used: 2

e. Description of Measures/Ratings: The two measures of TC-gunner performance were speed (time to engage the target) and accuracy (percent of targets hits).

f. Experimental Setting/Training Context: Testing of TC-

gunner pairs was conducted during morning and afternoon sessions in an institutional setting using a hands-on testing approach. A biographical questionnaire was administered to each subject prior to TGMTS testing. After each TC-gunner pair was tested, a second questionnaire was administered to assess user acceptance.

g. Statistical Methods: The test statistics used for data analysis were analysis of variance (ANOVA) and correlations. The Spearman-Brown formula was used to assess the reliability of performance measurement. Descriptive statistics were used to analyze the biographical and user acceptance data.

h. Stage of Training: Qualified M60A3 TCs and gunners.

5. Discussion:

a. Major Findings:

(1) Biographical data revealed that the TCs and gunners had an average of 8.42 years of armor experience and an average of 31 months as M60A3 crewmen.

(2) The correlation between the number of targets hit and range to target was significant ($r = -.58$, $p < .01$), meaning that firing accuracy decreased as distance to target increased.

(3) TC-gunner pairs engaged targets faster with the TGMTS after testing with the device. However, firing accuracy did not improve from one film to the next two.

(4) Gunners with more M60A3 tank gunnery experience had shorter engagement times and had more target hits than less experienced gunners. TC gunnery experience did not correlate with target engagement time or accuracy.

(5) Users' described TGMTS as challenging, interesting, realistic, and providing good practice for target acquisition and engaging moving targets.

b. Authors' Conclusions: The author concluded that TGMTS accurately measures tank gunnery performance. However, the TGMTS cannot be used to measure firing on the move, driving skills, or collective engagements.

c. Limitations:

(1) Prior crew or device familiarization could have had an effect on gunnery performance. Four of the 18 TC-gunner pairs previously trained together as TC and gunner. Six of the 18 TC-gunner pairs had previous experience with the TGMTS (about six sessions).

(2) User acceptance data revealed negative comments directed at film quality and the accuracy of the simulated round strike on the screen. Crewmen noted that the film was blurry and

targets were not clearly depicted against the background, thus making them difficult to detect. Crews also reported that the laser did not always hit where they aimed.

d. Considerations:

(1) Setting up and aligning TGMTS requires a moderate amount of technical expertise.

(2) The TGMTS can only be used to measure performance during daylight main gun engagements.

(3) Transfer of training was not conducted.

(4) The TGMTS is an individual gunnery skill training device which cannot be used to train collective gunnery skills.

6. Related Work:

a. Ogle, J. T. (1983). 1st battalion 77 armor gunnery study. Unpublished manuscript.

b. Sigtenhorst, K. H., & Johnson, J. R. (1982). Concept evaluation of institutional tank gunnery and missile tracking system (I-TGMTS) (TRADOC TRMS NO 2-CEP018). Fort Knox, KY: U.S. Army Armor Engineer Board. (AD B064 400)

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38. Witmer, B. G. (1988). 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)

1. Topic Keywords: Armor; M1 Tank; Tank Gunnery; Simulators; U-COFT; Degraded Mode Gunnery; Performance Measurement.

2. Short Summary: The Unit-Conduct of Fire Trainer (U-COFT) was used to examine effects of using degraded mode gunnery procedures on performance of experienced noncommissioned officers (NCOs). Using the Gunnery Index (Witmer, 1986) as measure of proficiency, gunnery performances under three different degraded conditions were compared to performance under fully operational conditions. Results suggested that using degraded procedures adversely affects the performance of experienced crewmen, with the most dramatic performance decrements occurring when conditions require the use of the Gunner's Auxiliary Sight (GAS). Performance did not improve significantly under degraded conditions after a brief period of degraded gunnery practice or the U-COFT, suggesting the need for specialized degraded gunnery training programs.

3. Performing Organization: U.S. Army Research Institute for the Behavioral and Social Sciences, Field Unit - Fort Knox, KY 40121-5620.

4. Approach: Experimental

a. Number of Groups: 4

b. Description of Groups: The subjects were 48 M1 qualified NCOs who were serving as instructors on M1 tank New Equipment Training Teams (NETT) at the U.S. Army Armor Center at Fort Knox. These instructors averaged 10 years in armor, two years as tank gunners, and 20 hours of U-COFT time. The subjects were assigned randomly to four groups of 12 subjects each. Three experimental groups were tested under degraded mode conditions while the fourth group, a control group, was tested in a fully operational mode. Before testing, all groups received 36 warm-up engagements (18 fully operational and 18 degraded) on U-COFT to familiarize them with required procedures and provide warm-up for the test.

c. Tests or Trials: The test consisted of seven U-COFT exercises comprising 60 single-target engagements. Exercises were selected on the basis of target range (short and long), and own tank and target movement (stationary-stationary, stationary-moving, moving-stationary, moving-moving). The combination of two ranges with four movement conditions yielded six engagement types. The order of target type presentation was counterbalanced across trials. Within each group, the subjects were randomly assigned to the six orders so that only two subjects from each group received the exercises in the same order. This procedure enabled the evaluation of practice effects across test trials.

d. Number of Different Types of Measures Used: 3.

e. Description of Measures/Ratings:

(1) U-COFT Gunnery Performance Data: Three measures of accuracy and one measure of speed were selected for evaluation purposes. The accuracy measures included average hit percentage, azimuth aiming error, and elevation aiming error. The speed measure was average opening time. These measures were calculated separately for each U-COFT exercise/engagement type. Average hit percentage was calculated by dividing the number of target hits by number of targets presented. Average azimuth and elevation aiming errors were computed by separately summing the azimuth and elevation aiming errors across each exercise and dividing the sums by number of targets engaged. Opening time was defined as the time elapsed between the target's first appearance and firing the first round. Average opening time was found by summing the opening times for an exercise and dividing by rounds fired.

(2) Gunnery Index: A modified version of the Gunnery Index (Witmer, 1986) was used in data analysis. The Gunnery Index is a composite measure of gunnery performance that combines various measures of accuracy and speed into a single measure of gunnery proficiency. It was computed for each exercise by combining weighted averages of opening times with average aiming errors and hit percentages. Opening times were used in lieu of hit times in this research because opening times tend to be more

reliable, especially for those exercises where few hits (and therefore few hit times) are recorded.

(3) Soldier-based Predictor Variables: The following variables from the biographical questionnaire were included in the analyses as measures of experience and ability: military grade or rank, age, education level, military service time, time in armor, time as gunner, time since last gunnery practice, hours of experience on U-COFT, and General Technical (GT) Score. GT is a composite score from the Armed Service Vocational Aptitude Battery (ASVAB). GT is composed of both verbal and arithmetic reasoning components, and considered roughly equivalent to intelligence test scores. Also, separate measures of time as an M1 gunner and as a gunner on other armor vehicles were obtained.

f. Experimental Setting/Training Context: The research was conducted in an institutional setting using a hands-on training and testing approach. Before the research began, five civilian research assistants (instructor/operators [I/Os] for the U-COFT) and four NETT instructors experienced on the U-COFT (surrogate tank commanders [TCs]) received training over a three-day period to assure standardized test administration procedures. Upon arrival at the test site, general instructions describing the purpose of the research and the experimental procedures were read to the subjects. Each subject was paired with a surrogate TC and took the gunner's seat in the U-COFT. Under the direction of the I/O and the TC, the gunners performed 36 warm-up engagements to familiarize them with the required procedures. After a 10-minute break, they performed 30 test engagements under either fully-operational or one of three degraded mode conditions. Following another 10-minute break, the subjects performed the remaining 30 test engagements. After testing was completed, the subjects completed a biographical questionnaire and a training strategies questionnaire.

g. Statistical Methods: Multiple analysis of variance (MANOVA) procedures from the Statistical Packages for the Social Sciences (SPSS-X) were used to determine the effects of degraded mode gunnery on gunner proficiency. The between-subjects variable was engagement mode (four levels). The within-subjects factors were target range (two levels) and tank-target movement (three levels). Four pairwise and one non-pairwise comparison were used to assess the effects of engagement mode on gunner performance. The first three contrasted performance under each of three degraded conditions with that under fully operational conditions. The fourth was chosen to determine if use of the GAS produced significant performance decrements. The non-pairwise comparison compared fully operational performance with the combined effects of degraded mode operation. The TRIALS effect was evaluated in an SPSS-X MANOVA with engagement mode (four levels) as the between-subjects factor and TRIALS (six levels) as the within-subjects factor. A significant trials effect would suggest that performance under fully operational or degraded conditions improves with practice under those conditions. An analysis of variance (ANOVA) was conducted on warm-up performance

to determine group equivalency prior to testing. Correlations between biographical measures and gunnery performance during the warm-up and on the test were computed to explore relationships between predictor variables and gunnery performance. Pearson correlation and stepwise regression procedures were used.

h. Use of Instructional Features: Standardized procedures were followed throughout warm-up and testing periods to ensure each gunner had an equal opportunity to identify and engage the targets. An operator's guide was provided to the I/Os which contained specific instructions for each U-COFT exercise, as well as detailed instructions for the gunner regarding fire control procedures to be used in each fire control mode. Instructions and setting of switches by the I/O and crew changed as a function of exercise and mode of engagement. The surrogate TCs were given a copy of the fire commands for each exercise along with general instructions to be read verbatim to the subjects.

5. Discussion:

a. Major Findings:

(1) Significant gunnery performance differences were found between fully operational engagements and degraded mode engagements during the warm-up/familiarization trials. That is, degraded conditions substantially reduced gunnery performance.

(2) Soldiers assigned to the degraded test groups and those assigned to the control group did not significantly differ in their performance on the warm-up/familiarization trials.

(3) Comparisons between the experimental and control groups' test performance showed (a) decrements in the performance of soldiers operating under degraded conditions, (b) performance varied as a function of engagement type with moving and long range targets producing poorer performance, and (c) size of the performance decrements depended on which fire control components failed (e.g., ballistic computer failure produced more severe performance decrements than other fire control system failures).

(4) Comparisons between pooled degraded performances and performance under fully operational conditions showed significant effects for tank-target movement, range, and interaction of these variables. Also, nonorthogonal contrasts indicated that (a) loss of stabilization produced no reliable decreases in the level of performance, (b) laser range finder (LRF) failure produced a significant adverse effect on performance that increased with target range, (c) loss of computer, gunner's primary sight (GPS), LRF, and stabilization produced the largest decrement in gunnery performance, mainly due to the requirement to use the GAS.

(5) The significant differences in test performance as a function of engagement mode also suggested that decrements due to degraded conditions do not quickly disappear with practice under these conditions.

(6) Gunnery performance was significantly affected by various own tank movement and target movement combinations. Similarly, target range significantly affected performance, with better gunnery performance exhibited for shorter range targets. Range also interacted with tank-target movement to produce a significant range by tank-target movement interaction, with a greater effect for moving targets than for stationary targets.

(7) The nonsignificant trial effect over the six test trials suggested that gunnery performance did not improve over six U-COFT exercises. The MODE by TRIAL interaction was also nonsignificant, which suggested that the trial effect did not vary as a function of engagement mode.

(8) When all biographical predictor variables were entered in a stepwise linear regression, only age significantly predicted performance (younger soldiers exhibited better gunnery performance). Also, the speed component, as measured by the Gunnery Index, declined with age but not the accuracy component.

b. Authors' Conclusions:

(1) The performance of experienced gunners is adversely affected by using degraded mode gunnery techniques, with the most dramatic performance decrements occurring when the degraded conditions require using the GAS (computer failure) or when they engage long-range moving targets without the benefit of the LRF.

(2) Performance did not improve significantly under degraded conditions after a brief period of degraded gunnery practice on the U-COFT, suggesting that performance decrements associated with degraded mode gunnery are not easily eliminated.

(3) Significant improvements in degraded mode gunnery performance may require either extensive practice under degraded conditions or use of special degraded gunnery training programs.

(4) Biographical variables are not reliable predictors of degraded gunnery performance. Gunner age was significantly correlated with performance but negatively, perhaps because of declining psychomotor abilities for older gunners.

c. Limitations: The reliability of the criterion measures and the overall test was not reported, nor was the reliability of the Gunnery Index used to analyze the data.

d. Considerations:

(1) A major problem in device testing has been the use of samples that are too small in relation to the variability of performance (N = 12 per group), so that the statistical power to detect differences of a reasonable size has been inadequate.

(2) A second problem in device testing is that the amount of training (fifteen percent of the soldiers tested had no

previous gunner experience, 79% tested had no previous M1 gunner experience, and average time spent training on U-COFT was 20 hours) may be insufficient to affect proficiency.

6. Related Work:

a. Department of the Army (1985). Tank combat tables M1 (Field Manual 17-12-1). Washington, DC: Author.

b. General Electric (1985). Instructor's utilization handbook for the M1 Unit-Conduct of Fire Trainer (U-COFT) (Vol.1). Orlando, FL: Naval Training Equipment Center.

c. Witmer, B. G. (1986). Gunnery indices as measures of gunnery proficiency. Paper presented at the 28th Annual Conference of the Military Testing Association, Mystic, Connecticut.

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

1. Topic Keywords: Armor; Training Transfer; Training Devices; Training Effectiveness; Tank Gunnery; Reliability; U-COFT; VIGS; Cross-training; Performance Measurement.

2. Short Summary: The Videodisk Gunnery Simulator (VIGS) and Unit-Conduct of Fire Trainer (U-COFT) were used to cross-train 24 soldiers from M60A3 armor units as M1 tank gunners. The subjects were randomly assigned to two groups of 12 subjects each; a VIGS-first group which trained on the VIGS and tested on the U-COFT, and a U-COFT-first group which trained on the U-COFT and tested on the VIGS. During training and testing each soldier engaged 54 single moving targets from a simulated stationary tank. The results revealed that gunnery performance improved as a function of training on each device, with larger improvements coming from the U-COFT. In addition, soldiers who fired more accurately with VIGS also fired more accurately with U-COFT, indicating that performance on VIGS may be used to predict U-COFT performance and vice versa. There was no evidence of VIGS to U-COFT transfer.

3. Performing organization: U.S. Army Research Institute for the Behavioral and Social Sciences, ARI Field Unit - Fort Knox, Fort Knox, KY 40121-5620

4. Approach: Experimental

a. Number of Groups: 2

b. Description of Groups: The subjects were 24 soldiers

from an M60A3 unit who averaged 17 months in armor and had no experience on the M1 tank. All subjects received a small amount of gunnery training before being assigned to their unit. Six reported serving as M60A3 gunners, averaging five months of gunnery experience. The other subjects' positions were tank driver (N=13), tank loader (N=3), jeep driver (N=1), and clerk typist (N=1).

c. Tests or Trials:

(1) VIGS-first Group: The subjects were 12 soldiers who received training on VIGS first and than tested on U-COFT.

(2) U-COFT-first Group: The subjects were 12 soldiers who received training on U-COFT first and than tested on VIGS.

(3) Both Groups: The subject's in each group received two training iterations; each iteration involved engaging 27 single moving tanks from a simulated stationary tank using the gunner's Thermal Imaging Sight (TIS), regardless of training device or phase (training, testing).

d. Number of Different Types of Measures Used: 11 (four measures of firing accuracy, three engagement speed measures, and four measures of procedural system management errors).

e. Description of Measures/Ratings: The four measures of firing accuracy were: (1) percent hits, (2) percent of first-round hits, (3) azimuth aiming error, and (4) elevation aiming error. The three engagement speed measures were: (1) hit time, (2) identification time, and (3) opening time. The four measures of procedural system management errors were: (1) selecting the wrong ammunition, (2) failing to activate the laser rangefinder prior to firing, (3) firing with the TIS in low power (U-COFT only), or (4) exposing their tank for more than 15 seconds (sec) before returning to a protected position (U-COFT only).

f. Experimental Setting/Training Context: The research was conducted in an institutional setting using a hands-on approach. Standardized sets of instruction were used for both training and testing. The engagements presented on the U-COFT and VIGS were similar, but the speed, direction, and exposure times differed between devices. After familiarization training, all soldiers received four warm-up trials. One VIGS instructor/operator (I/O) and three U-COFT I/O's administered the gunnery training. The U-COFT phase used three tank commander's (TCs), confederates of the experimenter, to assist the subjects. The tank gunner's were randomly assigned to the TCs, conditional upon each TC being paired with an equal number of gunners from each group.

g. Statistical Methods: The data were analyzed using the doubly multivariate repeated measures design from the Statistical Package for the Social Sciences (SPSS-X). The measures of firing accuracy, engagement speed, and system management errors were entered in a multivariate analysis of variance (MANOVA), with

repeated measures on the within subject variables. The within factors included the device (VIGS or U-COFT) and iteration (first or second). One between subjects variable, group membership, was included. Correlational analyses were performed to determine the reliability of the 54-item performance test used with each device and to discern the extent to which performance on one device predicts performance on the other device. The Spearman-Brown formula was used to correct for test length (Anastasi, 1968). The biographical variables were correlated with performance measures to identify other predictors of gunnery performance.

n. Trainee Sophistication: Novice

5. Discussion:

a. Major Findings

(1) Test-retest reliabilities for the VIGS and U-COFT 54-item test found that (a) for VIGS, the more reliable measures were hit percentage, first round hit percentage, identification time, opening time, and hit time and (b) for U-COFT, these same measures were also reliable with the exception of hit time. Aiming errors and system management errors were less stable.

(2) Examination of the variance for the performance measures supported the hypothesis that differential learning effects produced large decreases in variance from the first to second training replication, and that the largest decreases were for those measures showing low reliabilities.

(3) Significant correlations were obtained for three of four accuracy measures, but for none of the three speed measures. These results suggest that accuracy, but not speed measures may be predicted from one simulator to the other. That is, gunners who shot accurately on the VIGS also shot accurately on U-COFT.

(4) None of the individual ability/experience variables correlated with either VIGS or U-COFT measures. These results suggest that educational level, GT scores, or prior experience may not predict the gunnery performance of novice gunners.

(5) Separate training with VIGS or U-COFT resulted in significantly improved M1 gunnery performance between iterations. The results also revealed significant decreases in identification time, opening time, hit time (speed measures) and the number of procedural errors.

(6) The significant device by replication interaction from the MANOVA supported the conclusion that greater improvement occurred in U-COFT performance than in VIGS performance.

(7) No evidence was found to indicate that the skills learned on one device transferred to the other device. As such, there is no support for a VIGS, U-COFT mix in gunnery training.

b. Authors' Conclusions:

(1) The reliabilities of VIGS-based and U-COFT-based gunnery performance tests were high.

(2) Significant improvements in gunnery performance as a function of training were shown with each device, but the greatest improvements were with the U-COFT.

(3) Soldiers who fired more accurately on the VIGS also did so on the U-COFT, suggesting that VIGS performance is a good predictor of U-COFT performance and vice versa.

(4) Measures of engagement speed on the VIGS or U-COFT were not significantly correlated.

(5) None of the general ability or experience measures predicted tank gunnery performance.

(6) Transfer of training between the VIGS and U-COFT devices was not shown. As such, a tank gunnery training program combining these two devices cannot be recommended.

c. Limitations:

(1) The tank gunnery skill levels of the subjects were different. Six of the subjects had served as M60A3 gunners and 5 subjects had previously used a table-top gunnery training device. These prior experiences may have produced differences in gunnery performance not attributable to either VIGS or U-COFT training.

(2) Differences in device capabilities and the presence of different or confederate TCs during the U-COFT phase may have produced differences in engagement procedures and subsequent gunnery performance.

d. Considerations: The correlation magnitude required for statistical significance for a sample size of 12 would need to be .576 at $p=<.05$ or .708 at $p=<.01$ (Wert, Neidt, and Ahmann, 1954). Thus, only one of the four firing accuracy measures (first round hit percentage [$r=.58$]) correlated significantly ($p=<.05$) on VIGS and U-COFT, rather than three of the four measures as stated.

6. Related Work:

a. Anatasi, A. (1968). Psychological testing. New York: MacMillan.

b. SPSS, Inc. (1988). SPSS/PC+ V3.0 for the IBM PC/XI/AT and PS/2. Chicago, IL: Author.

c. Wert, J. E., Neidt, C. O., & Ahmann, J. S. (1954). Statistical Methods in Educational and Psychological Research. New York Century-Crofts.

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3. Bauer, R. W. (1978). Training transfer from mini-tank range to tank main gun firing (ARI Technical Paper 285). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A178 446)

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Appendix B

Abbreviated Descriptions of Armor Gunnery Training Devices

Armor gunnery training device descriptions are provided alphabetically in this appendix. In most cases, Field Manual [FM] 17-12-7 (Department of the Army [DA], 1977, 1988, 1992) contains thorough descriptions of each training device. In some instances supplemental information from additional sources was provided to augment the descriptions. Additional details about the device features or functions may be found in technical and research reports and instructor's guides and handbooks produced by the manufacturers and research laboratories.

Guard Unit Armory Device Full-Crew Interactive Simulation Trainer (GUARDFIST I). The GUARDFIST I is a tank-appended training device intended for use by Army National Guard (ARNG) units during inactive duty training (IDT) at local armories (DA, 1988; Daedaleen, 1990). It was conceptualized to be used to integrate computer generated imagery (CGI) with the controls and sights of an M1 tank. The device includes an instructor/operator (I/O) station, several components used to append it to an M1 tank, and an interface harness that connects the tank-appended parts to the I/O station (Landers and Hunt, 1991). Through separate monitors, the scene is concurrently presented to each crew member from their own perspective. The targets are generated and integrated into the scene for gunnery and driver training. The crew can fire and drive into the scene with full-crew interaction.

Institutional-Conduct of Fire Trainer (I-COFT). The I-COFT is a special configuration of the Unit-Conduct of Fire Trainer (U-COFT) manufactured by General Electric (1985). The I-COFT and U-COFT are almost identical with the exception that the I-COFT includes software options that permit training of either the tank commander (TC) or gunner separately. By means of an automated TC, the I-COFT can standardize the contributions of the TC in gunnery engagements.

M55 Laser Gunnery Trainer. The M55 Laser is a low-power gas laser that can be mounted in the tank's coaxial machinegun position or on a Brewster device and operated with vehicle power (DA, 1992). Each time the main gun firing circuit is activated, the M55 Laser device fires a single burst of red light. This light, visible through vehicle optics as a momentary red spot on the target, enables the crew member to determine how well he is laying the gun sights and tracking the target. In addition, a supervisory scorer can observe how accurately and proficiently the crew member is operating the vehicle's main weapon system. The device is good for single tank firing. It is not recommended for section or platoon firing because of the difficulty in trying to distinguish one laser light from another. This trainer allows tank crew members to train the proper techniques of (a) laying sights on a target; (b) tracking a target; (c) firing the main gun; and (d) adjusting the lay of the weapon on the target.

M60A1/M73 Coaxial Machine Gun (Single Shot Mode). This subcaliber device is an M73 coaxial machine gun equipped with an interrupter mechanism that restricts fire from the machine gun to one shot at a time (Rose, Wheaton, Leonard, Fingerman, & Boycan, 1976). Apart from this mechanism, the M73 machine gun operates normally.

Mobile-Conduct of Fire Trainer (M-COFT). The M-COFT is a transportable U-COFT composed of (a) a general purpose computer (GPC), which collects, translates, and calculates data during both device training and maintenance; (b) a special purpose computer (SPC), which generates the images viewed by the tank commander (TC) and gunner; (c) the Instructor/Operator (I/O) station, from which the instructor operates the firing exercise, interacts with the crew, and monitors the crew's performance; and (d) the crew station, which simulates the specific TC and gunner seats of a M1 tank (General Electric, 1985; Morrison, Drucker, & Campshure, 1991; U.S Army Armor Center, 1985). The M-COFT provides units in the field the opportunity to acquire, train, and sustain individual and collective armor skills in a manner similar to institutional U-COFT training.

Multiple Integrated Laser Engagement System (MILES). The MILES is a laser training system that simulates the effect of direct-fire weapons (DA, 1988). The MILES can be used for a two-sided, real time tactical engagement for up to battalion size units and can provide realistic casualty assessments. The MILES includes nine different weapon-fire simulator systems. Each utilizes eye-safe lasers and microelectronics to simulate firing rifles, machine guns, and other direct-fire weapons. Small battery-operated laser transmitters attached to conventional field weapons allow ground troops to fire invisible laser pulses, which are coded to distinguish the range and killing power of specific weapons, instead of live ammunition. Receiving detectors attached to opposing troops and vehicles pick up the laser pulses and provide instant audiovisual indications of a kill, hit, or near miss. Kill indicators on men or vehicles disable the victim's weapon. The hit and kill probabilities are similar to those for weapons using live ammunition. Rifles and machine guns fire blank ammunition, while missiles and main guns use weapon effect simulators to produce the noise, blast, and smoke. When the MILES is used for gunnery training with the laser target interface device (LTID), it is limited to degraded mode gunnery exercises.

Platoon Gunnery Trainer (PGT). The PGT consists of four M1 Unit-Conduct of Fire Trainers (U-COFTs) linked together by a Platoon Data Computer (General Electric, 1990; Kraemer & Wong, 1992). This prototype device is designed to familiarize Armor Officer Basic Course (AOBC) students with the fundamentals of platoon command and control and fire distribution, and to allow Active Component (AC) and Reserve Component (RC) units to train section/platoon gunnery skills through Tank Table (TT) XII, a live-fire tank platoon qualification course (U.S.Army Armor School, 1991).

SAAB BT-41 Tank Combat Simulator. The BT-41 is a tank-appended main-gun simulator employed in force-on-force tactical combat exercises (Melching & Healy, 1982). The system provides simulation of shots fired and evaluation of target hits. The device capabilities allow for shooting while in motion and at moving targets and provide natural feedback to the tank commander (TC) and gunner. The BT-41 has two major components; the Fire Simulator and Target Simulator. The Fire Simulator consists of the Fire Computer, Laser Unit, Display Unit, Printer Unit, Tracer Unit, Adaption Set, and necessary attachments compatible with the actual tank upon which it is to be mounted. The Fire Simulator simulates a projectile following a ballistic trajectory in true space toward a target reflector. The Target Simulator consists of the Target Computer, Reference Modules (which detect hits), Optional Hit Indicator, Printer Unit, and Adaption Set for mounting on the actual target vehicle. The Target Simulator allows indication and calculation of the hit-effect on the target vehicle.

Tank Gunnery and Missile Tracking System (TGMTS). The TGMTS is designed to train tank commanders (TCs) and gunners in proper gunnery techniques (DA, 1988). The TGMTS is a rear-screen film projection system which shows actual armor vehicles in realistic scenarios. It can display single and multiple targets at various ranges and speeds. The screen is placed in front of a single tank. An infrared line-of-sight projector mounted on the firing tank projects a pulsed infrared spot at the aiming point on the screen. An infrared position detector monitors the aiming point by constantly following the pulsed infrared spot. At the instant of projectile firing, a minicomputer determines trajectory simulation based on the gunner's aiming point and ballistic data. The precise position of the fired round is shown during flight. Upon impact, a brilliant point of light laser appears on the screen. The primary training value of the TGMTS is in TC-gunner coordination during engagement exercises. Adjustment of fire can be made as the gunner and TC receive a positive hit indication. Both battlesight and precision engagement techniques may be used with the TGMTS. However, the system does not provide tank motion capabilities and cannot be operated in cold temperatures.

Thru-sight video (TSV). The TSV records the audio and video of a gunner's performance and crew duties for after-action review (AAR) (DA, 1988). A television camera, linked to the gunner's primary sight (GPS) and wired to an equipment support enclosure (ESE) package, records the gunner's sight picture. The ESE package includes (a) a video cassette recorder (VCR); (b) time code generator (TCG) that superimposes real time or stopwatch time onto the recorded video tape; (c) events generator (EG) that superimposes a visual indicator on the video recording at the instant the gunner pulls the trigger; and (d) separate video player and television monitor for audio and video playback at the AAR site.

TELFARE. The TELFARE is a main gun training device that consists of a strap-on mount and uses caliber .50 M2 machinegun

ammunition as a substitute for the 105mm ammunition (DA, 1977; Melching & Healy, 1982). It is mounted on the main gun to allow almost full crew interaction on all types of engagements. The device requires no modification to the turret, cupola or fire control system and is accurate to 1000 meters with diminishing accuracy to 1500 meters. Because of range limitation, it is suggested that the device be used on 1/2 scale ranges using 1/2 and full scale targets.

TOPGUN. The TOPGUN is a low-fidelity, part-task, stand-alone trainer manufactured by NKH, Inc. (1986, 1988). It is modeled after a prototype device called "Battlesight" developed by Level II, Inc. for M60A1 gunnery (1985). TOPGUN was developed jointly by the Army Research Institute (ARI) and Defense Advanced Projects Agency (DARPA) to examine the utility of an inexpensive arcade-type video game for training and sustaining M60A3 and M1 gunnery skills. The device uses computer-generated (CG) graphics projected onto a 19-inch color Cathode-Ray Tube (CRT) designed to simulate the Gunner's Primary Sight (GPS), Thermal Imaging System (TIS), and Gunner's Auxiliary Sight (GAS). The CRT is partially masked to provide two distinct display areas; a reticle area and a gaming area. A computer-controlled audio system is used to provide battle sounds and the fire commands normally given by the tank commander (TC). The device also features a software-based performance measurement system (PMS) that enables flexible target programming as well as on- and off-line scoring of exercises. The PMS provides (a) time to fire; (b) time to kill; (c) azimuth and elevation errors from target center of mass; (d) hit percentage; and (e) a composite performance score which gives 100 points for a first round hit, 50 points for a second round hit, and 0 points for poorer performance. Operationally, the onboard computer evaluates the target threats, assigns them priority, and directs the engagements. The gunner engages targets, using gunner control handles (cadillacs) similar to those located in the tank for tracking and firing main gun rounds, in response to automated fire commands issued by the pseudo TC.

TPGID. The TPGID is a subcaliber training device intended to provide full crew training during the conduct of preliminary tank gunnery tables. It is designed to provide a full crew, live-fire training capability, without the constraints associated with full caliber, main gun ammunition. Technically, TPGID is a subcaliber barrel insert system whereby a 35-mm training round is placed inside a simulated 120-mm cartridge, which is then loaded in the tank main gun breech. This 35-mm training round is then fired through an inbore barrel which is mounted inside the tank main gun. After firing, the tank gun breech, assisted by a breech opening device, opens and ejects the expended, reusable adapter cartridge into a padded collection box.

Unit-Conduct of Fire Trainer (U-COFT). The U-COFT is a high fidelity stand-alone trainer built by General Electric (1985) for training tank commander (TC)/gunner pairs to perform crew gunnery skills required for armor combat in a simulated battlefield environment (DA, 1988; U.S. Army Armor Center, 1985). The

TC/gunner team moves through increasingly difficult training exercises based on computer assessment of their skills. An Instructor/Operator (I/O) monitors team progress and can select training exercises. Modes of operation include stabilization and non-stabilization, stationary and moving firing tank and target, single and multiple target arrays, day and night, reduced visibility conditions, and capabilities to engage targets in a Nuclear, Biological, and Chemical (NBC) environment. The U-COFT consists of four substations linked to an Ethernet controller that permits records transfer. The major subsystems include (a) I/O stations, (b) an enclosed crew station, (c) a special purpose computer, and (d) a general purpose computer. The I/O stations include separate monitors for TC and gunner sights, an I/O control terminal, and a printer for recording the crew's performance. The crew station contains the Gunner's Primary Sight (GPS), Thermal Imaging System (TIS), Gunner's Auxiliary Sight (GAS), the Gunner's Primary Sight Extension (GPSE) for the TC, the TC's Forward Unity Periscope (FUP), and nearly all the controls and switches used by the TC and gunner in the tank. The special purpose computer produces the computer-generated scenes presented through the TC and gunner sights. The general purpose computer provides control for the other U-COFT subsystems and manages the U-COFT training and evaluation system. The evaluation system reports three composite performance scores; Target Acquisition, Reticle Aim, and System Management. Each performance score is reported as a letter grade (A, B, C, D) with corresponding numerical values (4.0, 3.0, 2.0, 1.0). The Target Acquisition score measures "skills required to accurately detect, identify, and classify targets" and is determined by acquisition time and identification/classification errors. The Reticle Aim score assesses those "skills required to lay the reticle on the proper aiming point, fire at, and destroy given target(s)" and is computed from opening time, time to kill, and reticle aim error. The System Management score measures "the ability to operate as a crew, utilizing the correct principles and techniques of gunnery" and counts pre-firing switch errors, ammunition errors, and excessive own vehicle exposure times.

Videodisk Gunnery Simulator (VIGS). The VIGS is a medium fidelity, part-task, tabletop gunnery trainer, manufactured by ECC International Corporation (1988), that uses videodisk media to present target scenes or scenarios to a gunner (DA, 1988). The device includes a (a) gunner's console microcomputer, (b) videodisk player for generating the target scenarios, and (c) floppy disk drive to provide software control for the system. The gunner's console has a Gunner's Primary Sight (GPS) and Thermal Imaging System (TIS), power control handles (cadillac), main gun and coax switches, ammunition selector, and turret power control switches. Target scenarios are presented as either high-quality computer generated imagery or films of actual maneuvers. The scenarios can be programmed in any order to form missions and stored on a floppy disk. During target engagements, presented from a stationary or moving firing platform, the tank gunner can identify the targets and take the proper actions in response to automated fire commands. For M60A3, M1, and M1A1 versions, both

precision and degraded mode gunnery target engagements can be simulated. A target scenario summary, critique, and score can be used after each engagement to provide feedback. This feature allows the trainer to monitor gunner progress as the mission continues. For each mission, 100 points are awarded for rounds fired accurately and in the optimal time. Penalty points are given if the gunner fired too many rounds (-5), indexed the wrong ammunition (-30), fired at the wrong target first (-5), ambushed the target (-5), fired before the "fire" command (-10), used the wrong GAS reticle (-30), or failed to lase (-5). When more time is taken to fire than the optimal time, points are deducted as the difference from optimal time increases. In the prototype M1 version, optional components included a separate operator's station which consisted of an operator's terminal for initiating engagements, a performance monitor for observing the gunner's performance in real time, and a printer for producing a hardcopy printout of his performance.

3A102B Laser. The 3A102B laser device is a low-power gas laser mounted in the M73 coaxial machine gun bracket of the M60A1 and used to simulated main-gun rounds (Rose, Wheaton, Leonard, Fingerman, & Boycan, 1976). Once boresighted and zeroed, the gunner and tank commander (TC) use the existing main gun sights to acquire targets and the trigger to activate the laser, which emits a low-power red pulse. The laser beam does not simulate a tracer round that could be sighted to the target; rather, upon striking a target, the red-light return represents the shell burst. The device simulates the flight time of a real shell fired at a target. One notable limitation of this device concerns the 5-mil built-in lead that displaces the simulated burst 5-mils from the zero point. This built-in lead always places the simulated burst 5-mils in front of targets moving from left to right; however, when the target is moving from right to left and the crosshairs are placed on the target, the built-in lead incorrectly places the simulated burst behind the target (Rose, et al., 1976).

17-4 Burst-on-Target (BOT) Trainer (Green Hornet). The 17-4 BOT trainer is an altered version of the DVC 17-4 Conduct-of-Fire Tank Gunnery Trainer (DA, 1977; Wheaton, Rose, Fingerman, Leonard, & Boycan, 1976). The device consist of a wooden frame which contains a firing switch and mock fire-safe switch. A 27" x 27" painted terrain sketch is mounted on the frame. An equal-sized transparent plastic panel, with a circular aperture displaying an acetate reticle, is mounted directly in front of a painted terrain sketch. This panel is mounted in horizontal and vertical metal tracks, enabling movement in either directions. A metal plate, lying behind the terrain sketch, is attached to the moveable panel. When the front reticle panel moves, the rear metal plated simultaneously moves. A number of holes are drilled in the metal plate. When a small light is placed directly on one of the holes from behind, a burst appears on the sketch. To use this device, the gunner places the cross hairs directly on a designated target in the terrain sketch. Movement of the panel is accomplished through the use of two metal handles on the

bottom of the front panel. Trainees actually lift the entire panel in order to position the crosshairs on the target. Before each trial, the instructor places the rear light on one of the holes in the metal plate. Thus, when the trainee fires his first shot, the instructor simultaneously flips a switch in the rear of the device which activates the light. The trainee then sees a burst displaced from the target for about one second. Using this feedback, the trainee then determines a new aiming point and moves the crosshairs to the proper position. This process is continued throughout the training exercise.

17-4 Modified Burst-on-Target Trainer. The 17-4M is almost identical to the 17-4 device described above, but with three exceptions (Wheaton, Rose, Fingerman, Leonard, & Boycan, 1976). First, the painted terrain sketch in the 17-4M is not attached directly on the frame; rather, it is on rollers so that the scene can be periodically changed. Second, the instructor's switch to the light burst is attached to an extension cord. This enables the instructor to monitor and score the trainees performance more accurately. Third, the 17-4M is newer than the 17-4 device and thus, easier to manipulate.

17-4 Conduct-of-Fire Trainer (Wiley). The Wiley is a stand-alone gunnery training device that uses rear-projected slides to depict tanks at various ranges, in different terrains and orientations, through a regular M32 sight (Wheaton, Rose, Fingerman, Leonard, & Boycan, 1976). The device controls are physically identical to the traversing and elevating controls on the M60A1. Depressing the trigger activates a small laser inside the device, which then illuminates the rear-projected slide. Performance measures can then be calculated to determine firing results.

Note. Scaled ranges are used to overcome space and training limitations (DA, 1992). They allow for simulation of day and night main tank gun firing by tank, section, and platoon against single, multiple, stationary, and moving targets, usually with a subcaliber training device. The 1:30 and 1:60 scale ranges are used for single tank, section, and platoon stationary firing exercises. The ranges are typically configured like large sand-tables to resemble the actual battlefield. During training exercises, the controller uses a control box to activate targets. When the tank-to-target distance is less than 30 meters, crew members may not be able to see the target and reticle aim clearly. To accommodate for this difficulty a 1/16-inch hole is cut in an dark material and used to cover the eyepiece. This reduces the field of view enough to bring the target and reticle into focus. The TC cannot use the range finder, but all of the other crew duties for degraded engagement and battlesight can be exercised.

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